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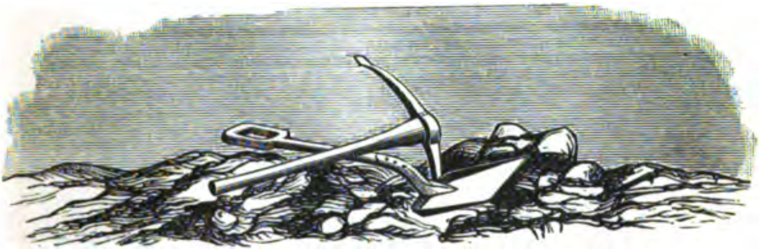

SEMER.

ERECTING
AND
OPERATING

AN EDUCATIONAL TREATISE
—FOR—
CONSTRUCTING ENGINEERS, MACHINISTS, MILLWRIGHTS AND MASTER BUILDERS

—BY—

WILLIAM ROGERS, pseud.

Author of "Mechanical Drawing and Design," "Pumps and Hydraulics," etc.

Hawkins, Nehemiah,

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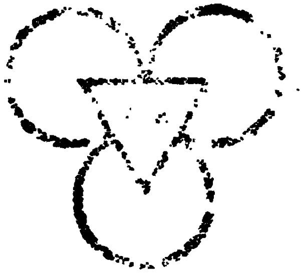

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AUTHOR'S PREFACE.

For a small monthly wage the author of this book held a position which made it his duty (1) to receive the product of the labor of fifty blacksmiths, to weigh the gross lots and to see that the hundreds of pieces were rightly made and distributed to the departments where they were used as parts of a whole; (2) his next duty was to inspect, weigh and distribute ten to twenty tons of castings per day in a similar manner, the two departments having been sublet to practical mechanics; (3) the position held also involved the ordering from the mills of the raw materials for the use of these and various other departments.

The plant covered several acres, fully occupied by foundry, machine, paint and other shops, while many gangs of men were putting up work in distant places. The number of employes was 700 to 1,000; now (4) the necessity was that the youth should know from personal observation and clear-headed attention, the hourly progress of the output of "the works" from the beginning to the finish. To obtain this result there needed to be—and there was—ready sympathy between the young assistant and blacksmiths, moulders, machinists, engineers, pattern makers, millwrights and draughtsmen.

The product of the works being principally iron and steel, in highly finished forms, it was essential also that the co-operation of superintendent, draftsman and other attachés of "the office" should be afforded. This co-operation was cheerfully given. Thus began an intimate and almost hourly "touch" between the author and "the men behind the tools," which was the beginning not only of life-long friendships but of a practical knowledge of shop detail as well as the erection and operation after completion of the "output" of the shops. This experience has been followed by years of devotion to mechanical pursuits; hence, not to make too long a story, the compilation and issue, at long length, of this volume, the personality of which has been briefly expressed in the "dedication" of the book.

The man selected to erect and put in operation the machinery built in the shop is one who is supposedly best fitted to perform the task. It is thus a matter of careful thought with the manager or owner to decide the question—whom to select. It may be well to note some of the reasons why one man gets the coveted task and another does not.

The selection upon the part of the manager begins with an elimination or casting out of many apparently capable men; of these, three-quarters would be crossed out for lack of skill—they are admirable machine-hands, but by reason of their limited experience, cannot fill the place. Skill and experience are widely different questions, and more than half the remainder on the list of men under consideration will be omitted from further consideration for lack of that wide experience which would enable them to grapple with new and untried situations.

In considering the man for appointment, the question of skill, or even experience, is not, as might be supposed, the first or last requirement; but something else, which may be covered by the one word—trustworthiness. Now if a man is known to be the most expert of mechanics, with a wide experience and entirely capable otherwise, and yet with a known weakness for strong drink, with a quarrelsome disposition, or untruthful habits, or even, worse than all, dishonest, he is rightly barred out, and a less skillful but more reliable man secures the coveted position.

To these plain words the author ventures to add a few others which he trusts will be received in the same spirit in which they are written—thus: When a shopman by whatever means becomes an outside man and in charge of assistants of various trades and often meeting "all sorts and conditions of men" he needs to exercise a few other very exceptional qualities than those in common use in daily shop practice. Besides his dearly bought mechanical skill, he needs *tact*.

NOTE:—The operation of this unwritten law is the cause of much which seems mysterious to many expert workmen; not thinking quite far enough, they consider that if they have the careful preliminary training in mechanics and the subsequent practical experience, they deserve promotion and the best positions. There are many fine occupations, both of honor and emolument, held by machinists and engineers; they have attained their places, and continue to retain them by an almost unexplainable force, i. e., that of a high personal character. Character and ability are decided by the best judges to be the main factors in a man's success; ability means ableness; character is the only thing that a man can distinctively call his own; it lies in the man; it is what he is; it is a positive thing, quite unlike reputation, which may not be at all as it appears.

In character building (1) dispense with boasting; (2) away with egotism; (3) avoid slang; (4) avoid evil communications; (5) cultivate the mind; (6) be truthful; (7) exemplify delicacy and propriety. Twenty clerks in a store. Twenty "hands" in a printing office. Twenty apprentices in a ship-yard. Twenty young men about a village. All want to get on in the world, and all expect to do so. One of the clerks will rise to be a partner and make a fortune. One of the compositors will own a newspaper and become an influential and prosperous citizen. One of the apprentices will come to be a master builder. One of the young villagers will get a handsome farm and live like a patriarch. But which is destined to be the lucky individual?

"Lucky"? There is no luck about it. The thing is almost as certain as the Rule of Three. The young fellow who distances his competitors is he who masters his business; who preserves his integrity; who lives cleanly and purely; who never gets into debt; who gains friends by deserving them, and puts money into the savings bank.

The word "tact" is equivalent to the word "touch;" it is that nice perception which comprehends everything relating to the order, formation, location and disposition of aught which bears upon the successful issue of an enterprise. The man of tact who has that presence of mind which can bring out of him on the instant what he knows of a subject, is worth for action a dozen men who know as much, but can only bring it to light more deliberately.

The man of tact "always knows more than he is expected to know," and especially he knows how to appropriate and use other men's brains and experience; he is a master of detail, has a definite aim, and goes straight for the target's "bulls-eye." He studies the peculiarities of those with whom he comes in contact, and talks and acts accordingly.

When a stranger in a strange place, having difficult and responsible work before him, the erector will, to his advantage, remember that first impressions are the most lasting. The qualities which at once win for the possessor the favorable opinion of those with whom he first comes in contact are : (1) bearing or carriage; (2) clothing; (3) voice; (4) manners. The old proverb that "clothes do not make the man" is quite a true one, but, nevertheless, the general opinion is that "clothes do count." They aid materially in characterizing the wearer, especially indicating the possession, or lack, of habits of neatness and cleanliness.

Foresight and prudence will also be found necessary for the

NOTE:—A young man once called on a gentleman of prominence; on taking his leave the youth requested the privilege of asking a question. "Why, sir," said he, "do you part with me with so much cordiality and warmth, when you received me with so much coolness?"

"Ah!" smilingly replied his host, "we receive our guests according to their appearance, but part with them according to their behavior."

erector. Foresight, from "seeing before" and forethought from "thinking ahead," denote a faculty of the mind for seeing the consequences of an act before it takes place; forecast, from "casting the thoughts onward" signifies coming at the knowledge of a thing beforehand, by means of calculation. There is a powerful element of failure in all undertakings of life. Men often reflect, "What shall I do if the enterprise I am about to undertake does not result as I wish and expect?"

Prudent management is the highest wisdom. Prudence is the result of judgment in providing beforehand the due means, order, reason, and method of doing or not doing.

Business management to a certain degree should engage the attention and study of the mechanic fitting himself for advancement. Something like the following is not amiss in the way of a suggestion:

> "George Washington's education was plain and practical. He never attempted the learned languages. His object, or the object of his friends, seems to have been confined to fitting him for ordinary business. Before he was thirteen years of age he had copied into a volume forms of all kinds of mercantile and legal papers; bills of exchange, notes of hand, deeds, bonds and other business forms.
>
> "This early self-tuition gave him throughout life a lawyer's skill in drafting documents, and a merchant's exactness in keeping accounts, so that all the concerns of his various estates, his dealings with his domestic stewards and foreign agents, his accounts with the Continental government, and all his financial transactions, are to this day to be seen posted up in his own handwriting, monuments of his methods and unwearied zeal and accuracy."

PART ONE

ERECTING

For "Operating" see page 431.

EXPLANATORY PREFACE.

Why this book and its methods? Because—

Owing to his natural limitations, man must work from a beginning and continue in a certain direction, doing one thing after another, until a conclusion is reached; the starting and the finishing of a desired accomplishment will be in the mind of the true author, even before the task is begun, while it continues, and to its end.

The book is primarily intended to be personal rather than descriptive of machines and devices, i. e., an educational treatise. The method is to deal with the various subjects, outlined in the Summary of Contents, under general divisions, indicating the path of study and investigation, rather than with chapters, consisting each of nearly the same number of pages.

By following this plan and with the aid of a full index to be found at the end of the volume, the work becomes a reference book, as well as a course of systematic study. Owing to this double use, the author need not refrain from repeating a principle or definition which may have been used in another place, because many things which the reader may wish to understand must be explained in connection with more than one subject, into each of which it naturally "dovetails."

After its personality, extending throughout the volume, it is in the scope of the work to explain the principles upon which machinery is designed and made ready for useful service. This in more pretentious works comes under the head of Physics, which has been defined as "that branch of science which treats of the laws and properties of matter and the forces acting upon it;

PRELIMINARY.

especially, that department of natural science which treats of the causes (as gravitation, heat, light, magnetism, electricity, etc.) that modify the general properties of bodies."

From the foregoing it may be inferred that the book deals with the elements or beginning of things—principally—but always in a suggestive manner, like the hand on a guide-post pointing the weary traveller in the right direction and without words, seeming to say "This is the way; walk thou in it." This suggestive method leads out to great expanses and in many directions, useful for the student to know about, calling for research, appealing to the imagination and perchance resulting in a fortune.

Next, the author of this work aims to classify its direct and suggested information so that it may be readily available, thus: the "Powers," electric, hydraulic, steam, etc., are grouped together; the "Foundations" precede Erecting, which in turn is followed by Transmission, etc.

Finally, all the "Art of Bookmaking" is used in printing, binding and its general make-up, possible to make a durable, handsome and useful book. This comes through a warm co-operation of the several efforts of author, printer, binder and publisher—"distinct like the billow, but one like the sea," in effecting the happy result—the production of a complete book.

PRELIMINARY.

"In order to become an adept at the erection and operation of complex modern machinery, judgment must be added to mere execution. Judgment cannot be taught in writing, further than in laying down certain principles of procedure. Constructive powers must work alone; inspiration must be from within; constructive work and organization work must be done alone; situations will arise when none can aid. Ultimately one must rely upon himself and this takes courage to the point of daring, infinite patience and native born wisdom."

To build is to frame, construct or erect; a builder is one who builds, especially one who controls or directs the actual work of construction; hence, this work might be properly called a builder's book were it not for the dignity and importance of the several trades almost equally interested with the builder in the successful outcome of the joint undertaking. The operations incidental to the working of crude materials into complete structures are varied and complicated; in the simplest building, experts belonging to many trades are represented; separate sets of workmen are employed, as a rule, from each trade.

The laborer performs most of the heavy work, such as unloading materials and supplying them to the skilled workmen—those who have received a training or apprenticeship in some craft requiring manual dexterity. Laborers also do excavating and concrete laying. Most important is the part taken by these—the lowest paid and often the least thought of workmem employed in pushing to completion an undertaking. Superior laborers are required as drain layers and for erecting and altering scaffolds—the latter are frequently termed scaffolders.

The tradesmen who are skilled artisans comprise the bricklayer, the mason, the carpenter, the structural iron and steel worker, the gas-fitter, the plumber, and the copper-smith. Some of the work by these is done outside and part of the materials may be prepared elsewhere, but in each department a great part of the work is necessarily executed on the spot. The other principal trades are those of the plasterer, the carpenter and joiner, the electrician, the painter and decorator, the glazier and the paper hanger. The services of the heating and ventilating engineer are also included. Fire-proofing, heating and ventilation is usually carried out by one or more of the above tradesmen under special supervision.

It is within the province of the builder to divide the execution of the work among the different trades, having due reference to the rules governing each organization. A general foreman is appointed by the builder, and his duties are numerous; not the least important is that of organizing the work of the different tradesmen so that they may follow each other without interruption and, if possible, without reducing, even temporarily, the number of men employed.

GLOSSARY.

A glossary is an explanatory vocabulary dealing with a special class of words belonging exclusively to a certain employment or science. *A dictionary* is a "word book" of a language; theoretically it contains all words, but the time has passed when a dictionary will be put forth which can within practical limits contain the words now current in the English language, of which it is estimated there are fully half a million.

Acceptance—(1) Receiving with approval what is offered. (2) The final approval and taking over a plant, machine, etc., from a contractor.

Alignment or alinement—The act of adjusting to a line; the line of adjustment, as, the "lining up" of shafting. In civil engineering this word is used to indicate the ground plan of a railway or other road in distinction to the grades or profile.

Attraction—An invisible power in a body by which it draws anything to itself; the power in nature acting naturally between bodies, or particles, tending to draw them together; the *attraction of gravitation* acts at all distances throughout the universe; *adhesive attraction* unites bodies by their adjacent surfaces; *chemical attraction*, or chemical affinity, is that peculiar force which causes elementary atoms or molecules to unite.

Batten—A piece of wood used to strengthen a part, cover a crack or fasten tarpulin down to ship decks.

Bevel—(1) Any angle other than a right angle. (2) Two surfaces at right angles; when the edge is chamfered, it is beveled.

Caliber—Measure of weight, or of size—to caliber a piece of metal is to measure it accurately with a caliper.

Cam—A rotating or sliding piece, which by its periphery or face, imparts intermittent or variable motion, to any piece that makes contact with its face.

Capstan—A vertical windlass.

Carpenter—A worker in timber, a framer and builder of houses, ships, etc. The carpenter frames and puts together the structural parts of a building. The joiner supplies the parts, such as stairs, doors, shutters, etc., necessary to finish the building.

GLOSSARY.

Chamfer—A slope, groove, or small gutter cut in wood, metal or stone.

Cleats—(1) A strip of wood or iron fastened on transversely to something for strength, to prevent warping. (2) A device made of wood or metal having two arms around which turns may be taken with a rope to hold securely and yet be readily released.

Cohesion—That force which binds two or more bodies together; that force which the neighboring particles of a body exert to keep each other together.

Crab—(1) A powerful winch or windlass provided with gearing used with derricks. (2) A claw for anchoring a portable machine.

Definitions—To define is to give the exact description of a thing, an act or a word; a marking out, or outlining; definition in meaning is closely connected with classification.

Design— (1) To mark out, to draw the preliminary sketch or outline the main features of an invention, machine, building or plan. (2) or it is the drawing produced.

Detail Drawing—One which is not a general drawing but embraces some portion or section only of a machine, setting forth every detail of the part.

Dowel—A pin of wood or metal inserted in the edge or face of two boards or pieces, so as to secure them together.

Drawing—The delineation of buildings, machinery and machine parts in plans, elevations and sections to proportional scales.

Dutchman—A piece of material like the structure, let into a slack place, to cover slack or bad work.

Edgewise—Standing with edge upwardly; hence endwise and sidewise have similar significations with reference to an end or side.

Elasticity—The property possessed by most solid bodies, of regaining their original form or shape, after the removal of a force which caused a change of form.

Erecting—This term is applied in large work, to the operations involved in fitting their parts to their places on the engine or machine, as well as placing them on their foundations and putting them together ready to run.

Erecting Shop—A place where large machines are put together and adjusted ready for testing before shipment.

Erector—A machinist or engineer whose special task is to take the separate work of the various departments of a shop and fit them together in their place to form a whole.

Excavation—A cavity formed by cutting, scooping or digging. The word is derived from the Latin, *cavus*, hollow, as is also the English word, cave. To *Excavate* is to dig out and remove, as earth for construction work.

Factor of Safety—The ratio between the breaking load and the actual load.

GLOSSARY.

Fatigue of Metals—In many cases materials are subject to impulsive loads and a gradual diminution of strength is observed; in part this deterioration of strength may be due to the ordinary action of a live or repeated load, but it appears to be more often due directly to the gradual loss of the power of elongation in consequence of the slow accumulation of the *permanent set;* the latter may be defined as the *fatigue of metals.*

Flange—(1) An external or internal rim for strength; (2) A plate or rim forming edge or end of pipe.

Finish—This word has come to mean not merely to complete in the essentials but to perfect in all the minute details.

Force—That which tends to produce or to destroy motion; if a body is at rest anything which tends to put it in motion is a force; *centrifugal force* is that by which all bodies moving around another body in a curve, tend to fly off from the axis of their motion; *centripetal* is that which draws, or impels a body toward some point as a center; *force* is equivalent to *push* or pull.

Friction—That force which acts between two bodies at their surface of contact so as to resist their sliding on each other, and which depends on the force with which they are pressed together.

Furrings—Strips of timber or boards fastened to frames, joists, etc., in order to bring their faces to the required shape or level.

Gin—(1) A machine for raising or moving heavy weights, consisting of a tripod framed of poles, united at the top with windlass pulleys and ropes. (2) A hoisting machine.

Gin-Pole—A pole forming a leg or support of a tripod used for scaffolding.

Gravity—Something which gives to every particle of matter a tendency toward every other particle. This influence is conveyed from one body to another without any perceptible interval of time.

Inertia—That property of a body by virtue of which it tends to continue in the state of rest or motion in which it may be placed until acted on by some force.

Inspector—One whose duty it is to look closely and critically in order to ascertain the quality and condition of materials used, to detect errors in construction and to conscientiously supervise the general progress of work, either in the shop or in the process of erection; his duties include the testing of materials and scrutinizing all details of a job, insisting that it be done in accordance with the plans and specifications furnished.

Installation—(1) A placing in position for service or use. (2) The whole of a system of machines, apparatus and accessories when set up and arranged for practical working.

"**Lining-Up**"—(1) Bringing in line. (2) A line is a slender cord used to find the proper relative position of the parts of machinery with a view

GLOSSARY.

to its smooth working; as, the engine is *in line* or *out of line*.

Load—There are two kinds of load: first, a *dead load* which produces a permanent and unvarying amount of straining action, and is invariable during the life of the machine—such, for example as its weight; and, second, variable or *live load*, which is alternately imposed and removed, and which produces a constantly varying amount of straining action. Every load which acts on a structure produces a change of form, which is termed the strain due to the load. The strain may be either a vanishing or elastic deformation, that is, one which disappears when the load is removed; or a permanent deformation or set, which remains after the load is removed.

Machine—In general, any device for the conversion of force and motion. *Tools* are the simplest implements of art; these, when they become complicated in their structure, become *machines*, and when they act with great power, take the name, broadly speaking, of *engines*.

Machines are divided into *simple* and *compound*. The simple machines are six in number, viz.:

The lever. The wheel and axle. The pulley. The inclined plane. The screw. The wedge.

These can in turn be reduced to three classes: 1. A solid body turning on an axis. 2. A flexible cord. 3. A hard and smooth inclined surface.

Machine-Work—Work done by a machine as distinguished from that done by hand.

Machinist—(1) One who makes or repairs machines or is familiar with their design or construction. (2) One who operates a machine.

Matter—Any collection of substance existing by itself in a separate form; matter appears in separate forms which however can all be reduced to three classes, namely, *solids, liquids, gases;* a *solid* offers resistance to change of shape or shape of bulk, always keeping the same size or volume and the same shape; a *liquid* is a body which offers no resistance to a change in shape and a *gas* or *vapor* is any substance in the elastic or air-like shape.

The two *essential* properties of matter, both of which are inseparable from it, are *extension* and *impenetrability*. Extension, in the three dimensions of length, breadth, and thickness, belongs to matter under all circumstances; and impenetrability, or *the property of excluding all other matter from the space which it occupies*, appertains alike to the largest body and the smallest particle.

Maul—(1) A large double-headed hammer. (2) A large heavy wooden beetle or mallet.

Mechanics—That section of natural philosophy or physics which treats of the action of forces on bodies. That part of mechanics which considers the action of forces in producing rest or equilibrium is called *statics;* that which relates to such action in producing motion is called

GLOSSARY.

dynamics. The term *mechanics* includes the action of forces on all bodies, whether solid, liquid, or gaseous. It is usually, however, used of *solid bodies* only.

Millwright—A mechanic whose occupation is to build mills or to set up their machinery.

Mitre—Two pieces of material cut out to an angle of 45° or two pieces—such as a wall, boards, or other material, joined so as to make a right angle.

Modulus—The primary signification of the *Modulus* is a measure; the modulus of a machine means the same as the *efficiency* of it. The modulus of a machine is a formula (or measure) expressing the work a given machine can perform under the condition under which it has been constructed; the words *mode*, *model*, *mold* are kindred terms, all formed from the same root-word and meaning somewhat the same.

Moment—The tendency, or measure of tendency, *to produce motion*, especially motion about a fixed point or axis.

Momentum—Impetus or push; it is the quantity of motion in a moving body; it is always proportioned to the quantity of matter multiplied into the velocity.

Mortise—A hole or cavity cut in any material to receive the end or tenon of another piece.

Motion—Signifies movement; in mechanics it may be either simple or compound, the latter consists of combinations of any of the simple motions. The *acceleration of motion* is the rate of change of the velocity of a moving body, in either an increasing or decreasing rate.

Newton's laws—As there are three states of matter, solid, liquid, gaseous, so there are three laws of motion. These are as follows:

LAW 1. "Every body continues in its state of rest, or of uniform motion in a straight line, except in so far as it is compelled by force to change that state."

LAW 2. "Change of (quantity of) motion is proportional to force, and takes place in the straight line in which the force acts."

LAW 3. "To every action there is always an equal and contrary reaction; or the mutual actions of any two bodies are always equal and oppositely directed."

Physics—The science which deals with the materials and forces of nature. An olden name for the same is Natural Philosophy. At this place and time we confine ourselves to the relative simple facts of matter, motion, energy, etc., useful to the student of structural mechanics.

Plant—The whole machinery and apparatus, including often the land and buildings employed in carrying on a business, as the plant of a foundry or mill; whatever represents the investment of capital used in carrying on the business, but not including material worked upon, or finished products.

GLOSSARY.

Power—The rate at which mechanical energy is exerted or mechanical work is performed, as by a steam engine, an electric motor, etc.

Properties of Matter—The quantity of matter which a body contains is called its *Mass;* the space it occupies, its *Volume;* its relative quantity of matter under a given volume, its *Density.* All bodies have empty spaces denominated *Pores.* The *mass* of a body, or the quantity it contains, is a constant quality, while the *weight* varies according to the variation in the force of gravity at different places. There are also several other properties which are known by experience to belong to all matter, as *gravity, inertia,* and *divisibility;* and others still which belong not to matter universally, but only to certain classes of bodies, as *elasticity, malleability,* or the power of being extended into leaves or plates ; and *ductility,* or the power of being extended in length, as when drawn into wire,

Purlin—A piece of timber laid horizontally upon the principal rafters of a roof.

Ramp—(1) A sloping line of a surface, as an inclined plane. (2) A short bend or slope where the hand-rail or cap in stairways changes its direction.

Rigger—One whose occupation is fitting ropes, chains, pullies, tackle and other hoisting devices, either on shore or on ships.

Scarf—To unite two pieces of timber at their ends by running the end of one over and upon the other and bolting or securing them together.

Seasoning—As applied to lumber or timber, evaporating the moisture in the fibrous part of the wood. If dried too rapidly it will cause an uneven shrinkage.

Shears—Elevated spars connected at the upper ends and used to elevate heavy bodies in a perpendicular position, as masts, etc.

Sholes—Pieces of plank under the heels of shores.

Shore—An oblique brace of timber or iron, the upper end resting against the substance to be temporarily supported.

Sill—A piece of timber upon which a building rests ; the horizontal piece of timber or stone at the bottom of a framed case.

Sketch—A rough, usually free-hand drawing made without rule or compasses, and therefore, though not to scale, a working drawing because furnished with necessary dimensions. Freehand sketches are used for rough and temporary purposes, or for those jobs which will not justify the cost of making regular drawings.

Specifications—A written statement containing a list of special items in which all particulars, both general and in detail, are set forth, respecting the construction of a machine or other engineering work. Specifications are issued for all important works and are binding upon the contracting parties.

GLOSSARY.

Stage—The interval or distance between two elevations in shoveling, throwing, or lifting excavated material.

Strain—The alteration in shape, as the result of the stress.

Stress—The re-action or resistance of a body due to the load.

Strut—Any part of a machine or structure the principal use of which is to hold things apart; the opposite of *stay* and *tie*. In general, any piece of a frame which resists thrust or pressure in the direction of its length.

Survey—(1) A particular examination or overlooking the extent and boundaries of a location for a building or steam plant. (2) Determination of area, the length and directions of boundaries and the contour of earth surface.

Tackle—The connection of two or more blocks and a rope.

Template—A wood or iron plate or bearing under the end of a girder to distribute its weight. A templet is a gauge, pattern or mold, commonly a thin plate or board, used as a guide.

Tenacity—The resistance which a body offers to being pulled asunder; it is measured by the tensile strength in lbs. per square inch of the cross section of the body.

Tenon—The end of a piece of wood, cut into the form of a rectangular prism, designed to be set into a cavity of a like form in another piece, which is termed the *mortise*.

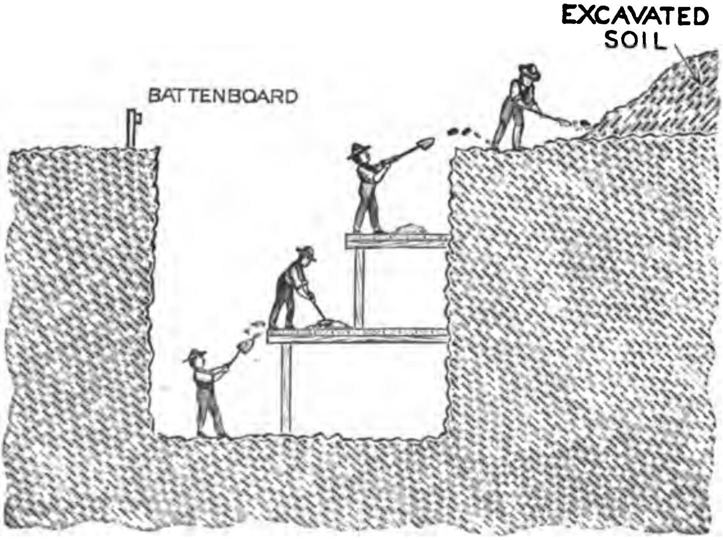
Timber—All varieties of wood, which when felled and seasoned, are suitable for building purposes.

Trestle—(1) A movable frame or support for anything, as scaffolding. A stool or horse as used by carpenters. (2) A framework of strong posts or piles and crossbeams for supporting a bridge.

Velocity—the rate of motion; in kinematics, *speed* is sometimes used to denote the amount of velocity without regard to direction of motion, while *velocity* is not regarded as known unless both the direction and the amount are known. *Linear velocity* is the rate of motion in a straight line, and is measured in feet per second, or per minute, or in miles per hour. *Circular velocity* is the rate at which a body describes an angle about a given point, and is measured in feet per second or per minute, or in number of revolutions per minute, as is a pulley or shaft. *Uniform velocity* takes place when the body moves over equal distances in equal times. *Variable velocity* takes place when a body moves with a constantly increasing or *decreasing speed.*

Work—The overcoming of a resistance through a certain space; it is measured by the amount of the resistance multiplied by the length of space through which it is overcome.

Working drawing—A very plain, fully detailed drawing of an engine, machine or structure, or more generally a portion only of the same.



See Page 43.

WORKING DRAWINGS.

Drawing is not only a universal language, but the shortest of shorthands; even a little sketch is sometimes able to explain a contemplated work better than hundreds of words.

No construction should be undertaken without first having advance drawings. By these, one is able to see ahead what improvements may be made in the plans; it is also convenient from the drawings to estimate the materials wanted, cost of labor, etc. It would be possible to build machines and other structures without the aid of drawings, but such a procedure would involve an increase in the time and effort required. Thus it appears that drawings are essentially labor-saving.

Before the erection of a building, drawings, generally to a scale of ⅛ inch or ¼ inch to the foot, are prepared, and show the work to be executed. These show, or should show, plans of (1) each floor or story, of (2) the foundations and roof, and (3) of the light and drainage; (4) elevations of all sides of the building, and (5) two or more sectional plans of different parts of the building, the number depending upon its size and complication.

A working drawing should be made, primarily, as plain as possible by the draughtsman; secondly, the workman should patiently and carefully study it, so that he thoroughly understands the object it is intended to represent, and that he may fill out, in imagination, the parts designedly left incomplete—as in a gear wheel where only two or three teeth are drawn in, that he may see, mentally, the whole.

WORKING DRAWINGS.

A free-hand drawing is executed with the unaided hand and eye, without guiding instruments or other artificial help. It is necessary to be known that all the drawing required in the office and shop cannot possibly be done by rule and compass, but that some portion must be drawn "free-hand," trusting to the eye alone. Hence, it is important that the erector should be able to sketch at sight from objects he may see, or to draw roughly with a piece of chalk or a pencil pieces of mechanism required to be represented.

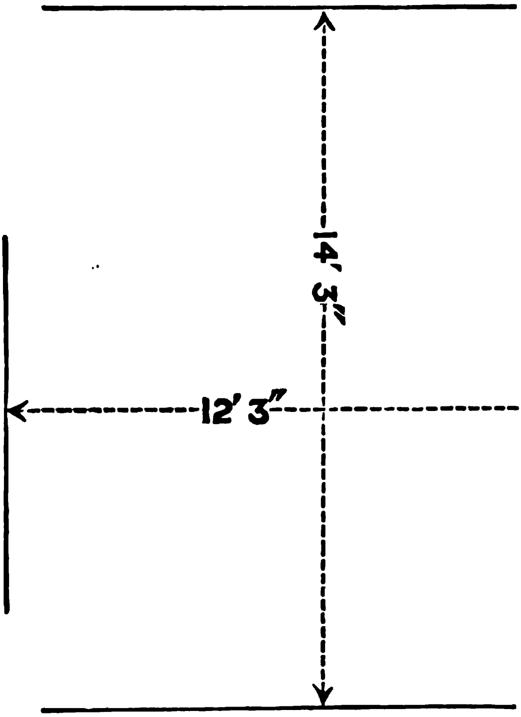


Fig. 4.

NOTE.—The text to accompany the above figure and others following will be found beginning on page 39.

PLANS AND BLUE PRINTS.

In many ways well made plans, giving all details, are a help in construction; but as with books, so it is with plans—one must get used to the author. Even as there are general or standard grammar rules, so there are standard or general rules in drawings, some of which are explained and illustrated in the following pages.

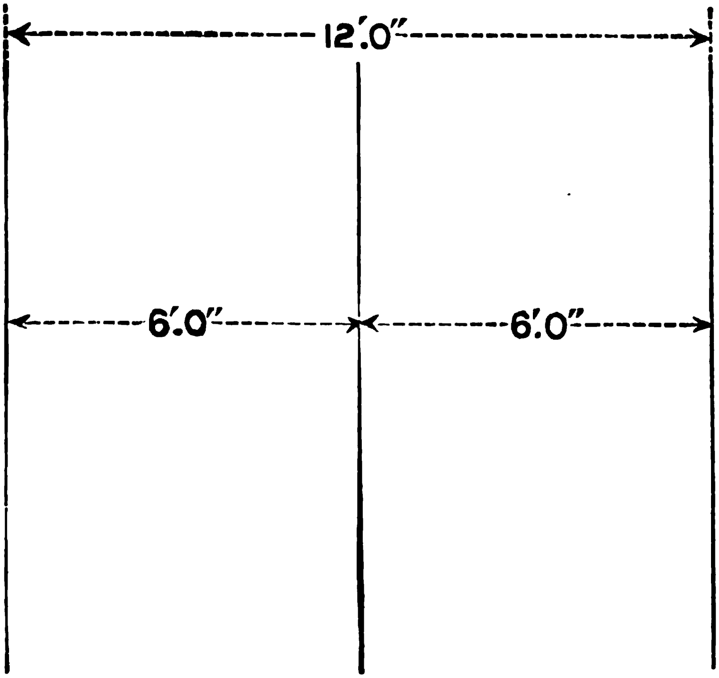


Fig. 5.

A number of ***drawings or blue prints*** should be provided for the purpose of conveying a full, clear and correct conception of the form and dimensions of the objects which are to be constructed, so that the work can be done without consulting the draughtsman or any one else, as far as the construction is concerned. A drawing which accomplishes this purpose can properly be called a good drawing, however rough it may be.

The terms, "general plans" and "detail drawings" are used in an opposite sense. Usually, *a general plan* is understood to present one or more views of a complete machine or structure, showing all the parts; and *a detail drawing* is understood to show separate parts of the same machine. The *general drawings* are supplied to the builder by the architect; they are drawn to scale and should indicate, in as much detail as possible, all the work to be executed as far as it can be foreseen. They form the most important source of information that the builder has regarding the disposition of the building. Copies of all of them, or of the most important, are submitted to the local authorities before work is begun. Both the foreman and clerk of works should have a complete set of general drawings of the works in addition to the set given to the builder.

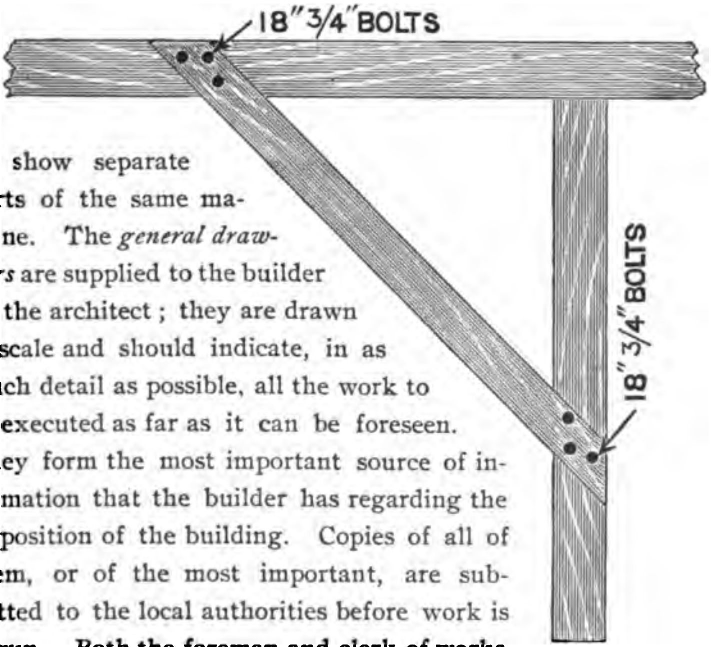


Fig. 6.

For objects of simple form, three views are generally sufficient, sometimes even two views will be all that are needed; but for a piece of more complicated form, more than three views, including one or more sections, may be required; but anvthing

BILLS OF MATERIAL.

more than the workman actually needs only detracts from the clearness of the drawing.

A "Bill of Material" is also indispensable. For each order of work, no matter how small, a bill for the material should be issued which should specify all the articles that will be required on the job. The form of the bill should be ruled for the items of the bill; also with columns provided with printed heads indicating their use.

Principal columns should be provided for Check Mark, Item Number, Detail Number, Number of Pieces, Kind of Material, Dimensions, Pattern Number, Drawing Number, Finished Weight, Rough Weight and Inspector's Check, and destination within the shop with respect to the various departments; also a space for a description of the details and materials entering into the construction.

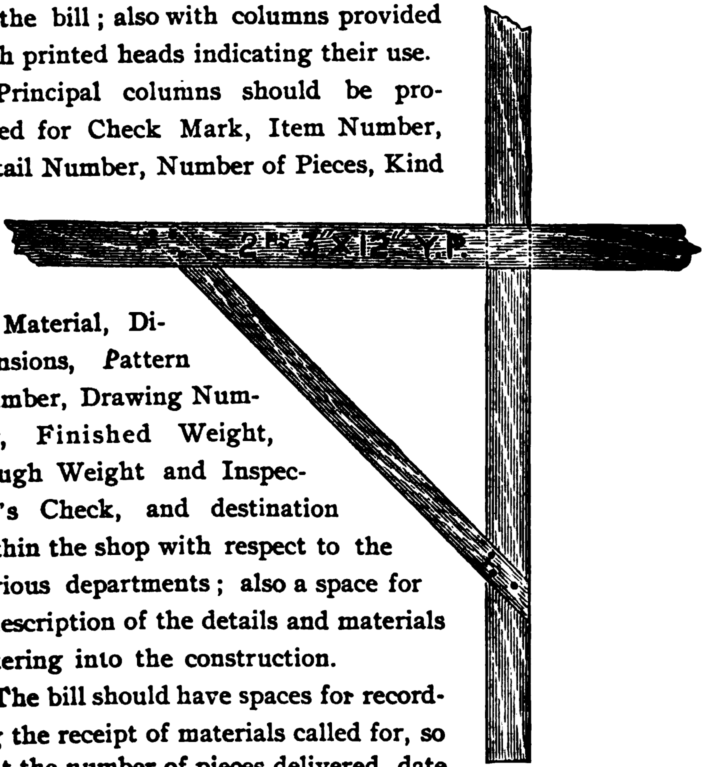


Fig. 7.

The bill should have spaces for recording the receipt of materials called for, so that the number of pieces delivered, date and the delivery card number can be entered. Sufficient spaces should be provided so that if 100 pieces are called for of a given pattern number, and if they be delivered at different times, the receipt of each lot can be recorded. The bill should be arranged so that it becomes a record of what has been done on the order.

The bill of material should give *the order number* and should also have space for the title in which is written, who the work is for, description, also spaces for the page number and for designating the final page, so that those concerned can tell when the bill is complete, as it is often very desirable to start work in parts before the entire bill can be written out completely, and before the drawings are detailed.

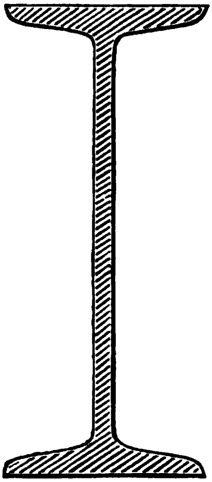


Fig. 8.

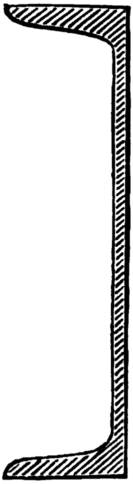


Fig. 9.

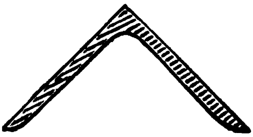


Fig. 10.

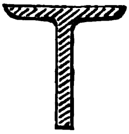


Fig. 11.

With many firms, it is a rule to have a bill of material made on the sheets of the detail work and the several pieces of construction or machinery marked with a capital letter. This letter is given on the bill of material with all the particulars of what kind, length, size, weight and also the *foundry* number. It is important every time a piece is put in construction to mark

PLANS AND BLUE PRINTS.

same off the bill and to see that all the dimensions conform with the bill. It is advisable for the man in charge to see before he starts on the construction that *all the material so marked is in hand.* This will give him a chance to report the shortage in case some of the articles are not shipped, and thus causing a delay of the work when once started on the erection.

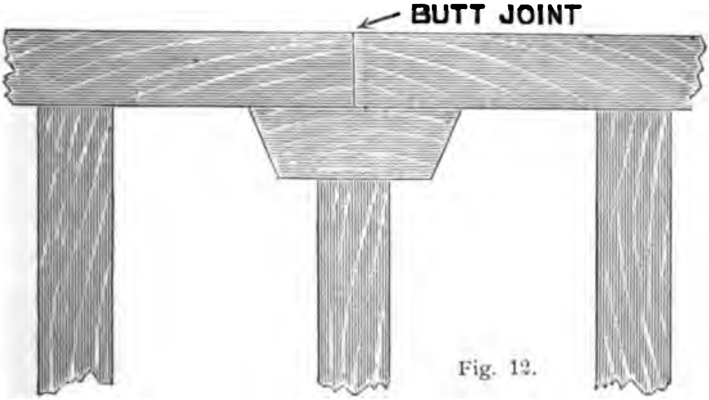


Fig. 12.

Blue prints, or copies of plans and drawings, printed by sun or electric light, are generally used by the erector; it is very seldom he gets the originals. As these prints give all lines, dots, and figures, as they appear on the drawings, they are most essential for the use of the erector, who should hold the reading or title to him—as he would read a letter—in studying them. It need not be said that the erector when receiving his blue print should familiarize himself with (1) the general size of the building or machinery; (2) the scale in which the drawing is made; (3) the kind and all the details of construction as far as they can be foreseen.

WORKING DRAWINGS.

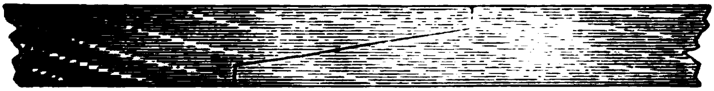


Fig. 13.

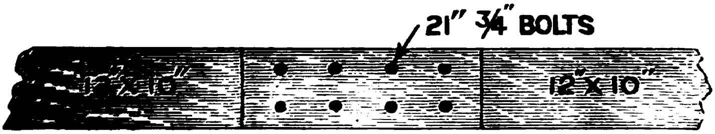


Fig. 14.

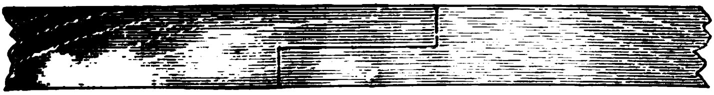


Fig. 15.

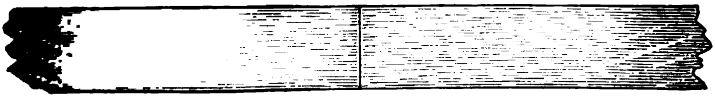


Fig. 16.

Note.—A detail drawing, whether made to a scale or not, must have all the dimensions plainly written upon it, for a workman should never be compelled to measure a plan or blue print.

WORKING DRAWINGS.

If dimensions are marked by figures, they are expressed thus —′ for feet, and ″for inches; example: 1′2″=one foot, two inches; 0′2″ or simply 2″=two inches; 2′0″=two feet; these marks should be clearly made on the drawing. <, or arrow-heads, mark the extremity of a dimension line, as in figures 4 and 5; thus in the figure the distance between the two arrow-heads on the same line is the measurement to which the figured dimensions refer.

If two dimensions meet on the same line, a cross (x) is often used, as in the centre of figure 5, page 33.

In placing notes or written instructions respecting details on a drawing, it is customary to draw a line leading from the written notes, terminating in an arrow-head at the point referred to as shown in figure 6.

When it is intended to represent two pieces of material crossing each other, that to the rear is shown with dotted lines, as in figure 7. Figure 6 shows that the brace is fastened to the side of the post and girder, nearest one, whereas in figure 7 the girder is double and lies each side of the post and brace, while the lower portion of the brace rests on *the near side of the post.*

If the size of material be mentioned on the drawing, and a figure 2 is placed before it, it denotes that the material is to be doubled, as is figure 7, 2—3 x 12 Y. P. directs the use of two scantlings of 3″ x 12″ Yellow Pine. Γ or L denotes angle-iron, T stands for tee-iron, and I symbolizes H or I section iron on a drawing. See Figs. 8–11.

In working drawings intended for the pattern shop or smithy, it is usual to mark the edges which require machining, with red ink or a heavy dotted line, so that proper allowance can be made for the machining.

WORKING DRAWINGS.

A group of illustrations, Figs. 12 to 17 inclusive, show some of the chief ways of representing the framing of woodwork.

The *diagonal scarf*, Fig. 13, sometimes termed a long splice or a ship splice, makes an efficient joint, more especially for resisting cross strains, when the scarf is vertical ; that is, assuming that on the page, *we are looking at the top of the beam.*

The length of scarf should vary from three times the depth, with hard woods such as oak or elm, to six times the depth with straight grained woods as pine, etc.

Fig. 14 shows the method of fishing or reinforcing the joint or scarf with *splice plates* on each side fastened by bolts, thus making it as strong as the solid beam itself, minus the area of the bolt holes. The unfished scarf has a strength only of about one-third that of the solid timber.

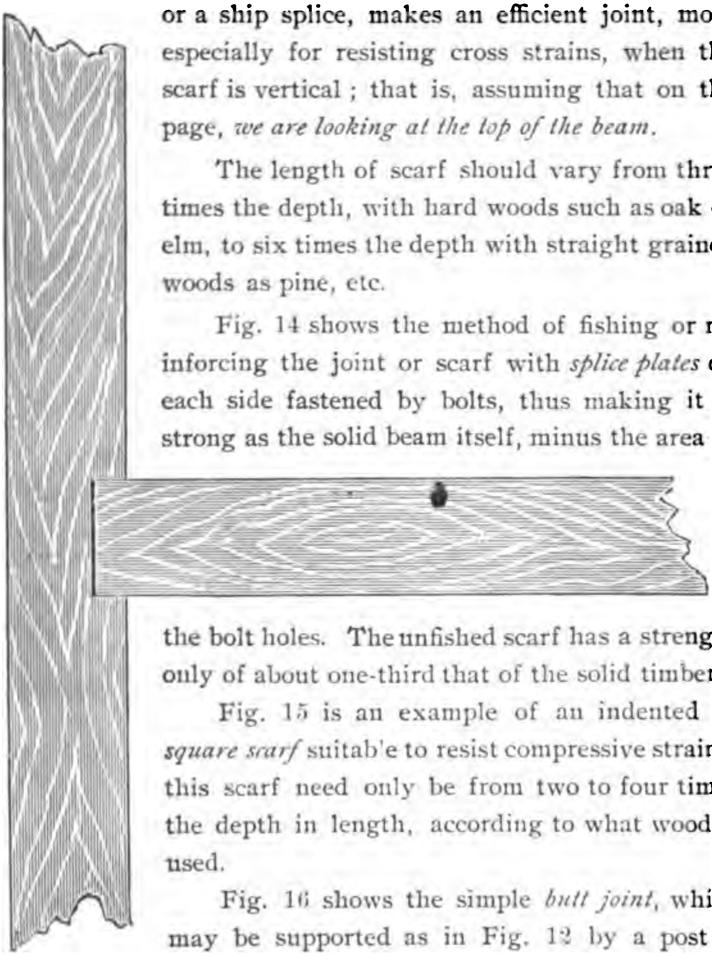


Fig. 17.

Fig. 15 is an example of an indented or *square scarf* suitable to resist compressive strains; this scarf need only be from two to four times the depth in length, according to what wood is used.

Fig. 16 shows the simple *butt joint*, which may be supported as in Fig. 12 by a post or shore, having a cap-piece equal in strength to the beam itself, and equal in length to three or four depths. A

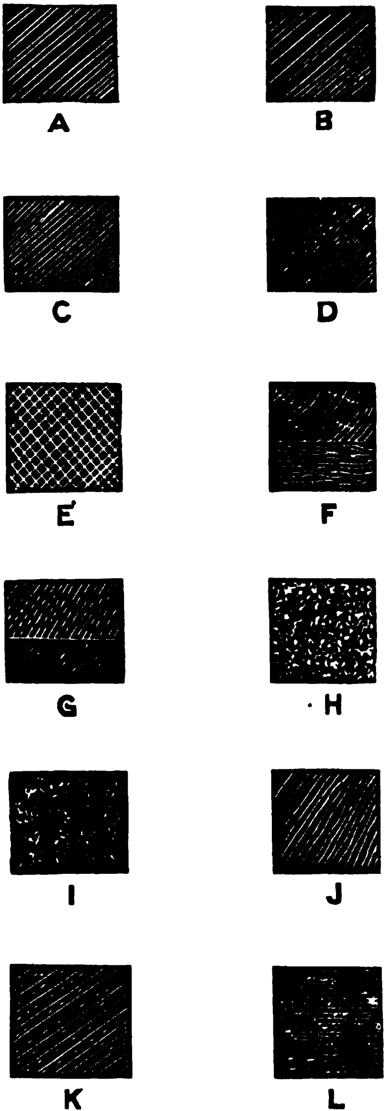
WORKING DRAWINGS.

satisfactory butt joint can be made with splice plates of iron, or iron above and wood beneath, or both of wood, care being taken that the sectional area of iron splice plates and bolts is equal to one-fifth that of the beam minus one bolt hole, and the combined area of the wooden plates is equal to that of the solid beam.

Large washers 3 to 4 times the diameter of the bolts should be used.

Fig. 17 represents the fitting of a crosspiece into an upright by means of a square recess measuring in length one-third the depth of the crossbeam.

As drawings are reproduced in line only by the blue print process, it becomes necessary to substitute section lines or symbolical hatching for the conventional tints used in drawings to represent the various materials in section. These lines are mostly drawn at an angle of 45°.



Figs. 18 to 29.

SECTION LINING.

The best way to indicate on the drawing the surfaces which are to be finished, is to write on the lines which represent the finished surfaces "finished," "tool-finish," or "faced," according to the degree of finish required. The single letter *f* is frequently used.

A sloping line should never be used in writing fractions on a drawing. The objection arises from the fact that such a dimension as $1\frac{3}{16}$, if written with the inclined line, unless very distinctly executed, may read as $\frac{13}{16}$.

Mechanical construction drawings represent a large amount of mental and manual work, as well as a considerable cost in money; hence, they are of value quite as much as other property which has been acquired by the expenditure of either labor or capital: therefore it is wise to keep copies of original designs and sketches.

Figs. 18 to 29 represent a number of the conventional linings used to represent materials in section.

A or two light lines close together indicates *steel*;

B or one light alternating with one heavy line denotes *wrought iron*;

C equal light lines, represents *cast iron*;

D is the sectioning used for *copper* or *brass*;

E the cross hatching to indicate *lead, white metal*, etc.;

F represents *wood*, the upper half across, the lower half with the grain;

G is a conventional representation of *stone* or *glass*, in section and in elevation;

H serves to indicate *concrete*;

I and J for *leather* and *rubber* respectively;

K is frequently used to show *firebrick*;

L is a common mode of representing *water*.

FOUNDATIONS.

A foundation is the basis or groundwork upon which anything stands, and by which it is supported or sustained. The solid ground or substructure on which the walls of a building rest, or the lowest division of the building or wall, which is generally below the surface of the ground, are the foundations.

Foundations may be divided into two classes, (1) natural and (2) artificial.

The first class may be again divided into foundations *on dry ground* and *foundations under water.* Under the first of these subdivisions several cases may be considered, depending upon the character and position of the bearing stratum. If this be of solid rock or indurated gravel, no further precaution will be required than to level the foundation pit, so that the masonry may start from a horizontal bed. Any irregularities which may occur, should be filled with concrete, rather than with masonry, as the compression of the mortar joints in masonry will inevitably cause irregular settlement, unless cement is employed and the mortar joints kept as close as possible.

Artificial foundations may also be divided into ordinary foundations, and foundations under water. Of the first kind we have two general cases: 1, when the ground is soft but not fluid; and 2, when it is of a semi-fluid nature. Soft ground may either be consolidated by driving piles into it until it becomes so compressed as to prevent the piles from sinking by the lateral friction produced; or a platform of fascines, timber, or concrete may be interposed between the surface of the ground and the superstructure, thus distributing the weight of the latter over a large extent of bearing surface.

NOTE—The fig., page 30, represents an excavation by "cut-and-cast," the waste material being thrown out in three stages. Temporary platforms have been erected for that purpose, as shown in the illustration.

FOUNDATIONS.

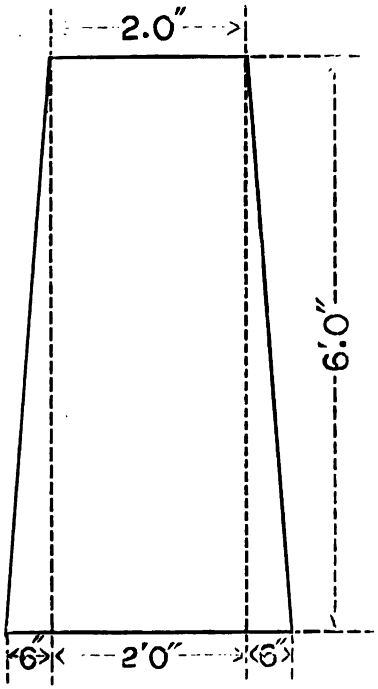


FIG 30.

For foundations under water, it is often sufficient, and generally feasible except in the case of a rock bottom, to bring up a number of isolated supports or piles. In other instances, however, a solid foundation is required, and this can be laid on the ground unless there is liability to scour, or the firm ground underlies a soft stratum which must be removed; in either of the latter instances, the water must be temporarily excluded from the site of the foundation. If the ground be of tolerable firmness, it may be enclosed with a dam; but there is always danger of the bottom being lifted by the pressure of the water, so that weighting the ground with planking and stones, is generally resorted to as a

---

NOTE.—A fascine is a round bundle of rods or sticks bound together, used in building earth-works, filling ditches, etc., and also protecting river-banks and constructing dams and jetties. These are much used by the Dutch in their hydraulic works, and the fascine beds are often of large dimensions and several feet in thickness. The bundles of fascines cross each other at right angles, and are securely bound with tarred rope and strengthened with poles and wicker bands; after being weighted with gravel and broken stone, they are sunk when required by means of guide ropes, and afterward secured by long stakes and piles driven through them.

FOUNDATIONS.

preventive measure. If the ground is semi-fluid, the best mode of proceeding is to sink the work in large caissons, the bottom having been first covered with a bed of fascine work, weighted and sunk with stones or brickwork as explained in the note at foot of page 44.

In many cases iron cylinders or caissons have been forced down to the rock, and then filled with concrete.

Where the ground is soft to a great depth, a large "raft" of concrete is used to spread the weight of the building over a sufficiently large area. Sometimes a wide trench is excavated, and filled with carefully rammed sand, which is prevented from escaping sideways by means of sheet piling.

Made ground should not be trusted, at least for the support of other than light weights, even if it has lain undisturbed for a long period.

Gravel forms one of the best of soils on which to build, being nearly incompressible, easily levelled, and unaffected by exposure to the atmosphere. Sand is good if dry, but it is liable to be washed away, or disturbed by alteration of the water level, as through pumping operations, etc.

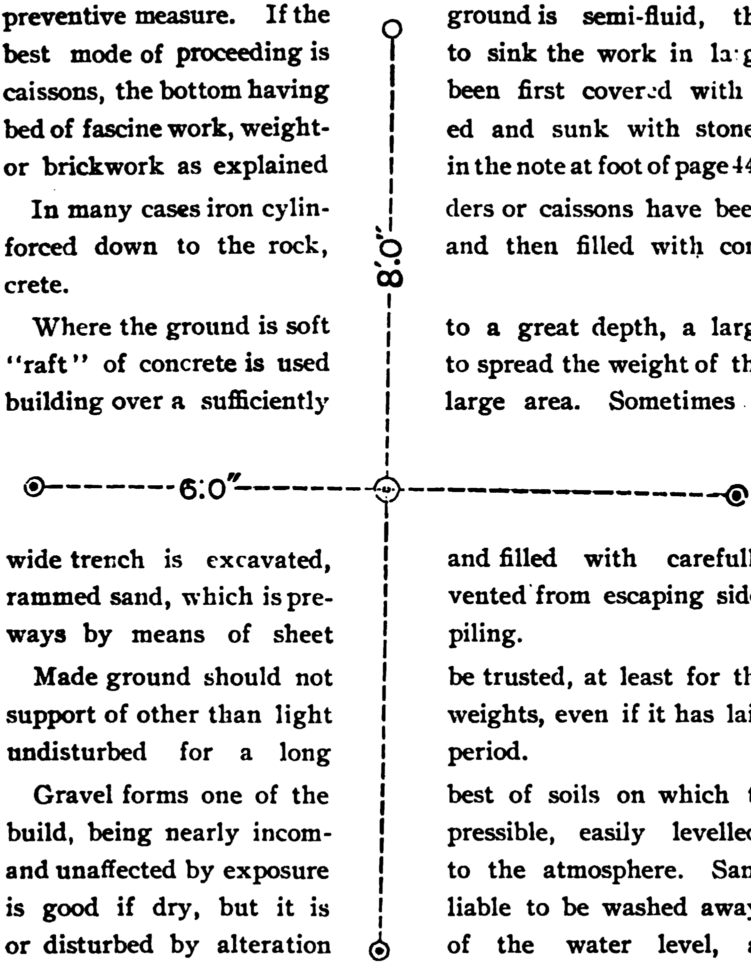


Fig. 31.

Quick sand, is sand and water so soaked, and so mobile, that it is liable to undo the most careful estimates.

FOUNDATIONS.

Rock makes a good foundation, but it must be levelled in terraces or steps, never left at an inclination under foundations; all decayed and loose rock must be removed, and openings and crevices filled with concrete, or firmly cemented masonry.

Clay is generally treacherous and damp; the foundations must be deep, and care exercised that seepage of water does not convert the clay into mud to be washed out, producing subsidences.

In cases where doubt exists of the nature of ground in which foundation works are to be executed, it is advisable to make trial borings with a post hole auger, and get samples of the underlying strata. Should the depth be over ten or twelve feet, a pipe may be inserted into the hole to prevent caving, and a smaller auger used to continue the boring.

Where soft strata overlie firm ground, the foundations should, where practicable, be carried down to this firm stratum; if impossible to do this, piles may be driven into the firm ground to support the building or brickwork.

Where sand or gravel overlies clay on sloping ground, a drain should be made at the higher side of the building so as to inter-

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NOTE.—All buildings settle more or less for an indefinite time after their construction, hence the question really is rather to restrict settlement within limits, than to attempt to prevent it altogether. The great desideratum is uniformity of movement, which is best attained by proportioning the width and size of the foundations to the superimposed weight. It may be as dangerous to give too much foundation as too little.

cept water from the foundations. The foundations should be carried down to such a depth as to escape the effects of heat and frost, and the action of surface water.

Footing courses, as the stepped or splayed out lowermost courses of a foundation are termed, should therefore be proportioned to the nature of the ground on which they rest, and to the weight of the load they are to carry. It is advisable so to arrange the footings that the centre of the load coincides with the centre of the base or support, but if that is not practicable, the better course is to have the centre line of the load *within* the centre line of the footing, as in that case the wall would tend to tilt *inwards,* which would be resisted by the various floors and beams, whilst in the *outward* direction, shores or buttresses would be necessary, and most probably could not be allowed.

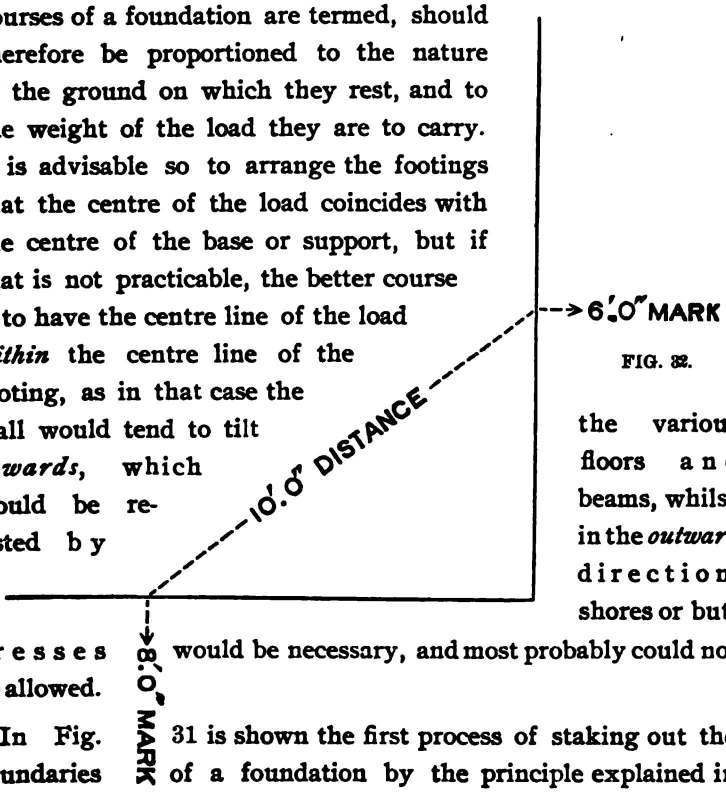


FIG. 32.

In Fig. 31 is shown the first process of staking out the boundaries of a foundation by the principle explained in Fig. 32. The centre line having been drawn, a distance of eight feet is marked off each side of the proposed centre, and the cross line is marked off six feet from each side of the same centre, so that the ten-foot pole exactly measures the distance between the points on the lengthwise line and the cross line, thus showing that they are at right angles with each other.

STAKING OUT.

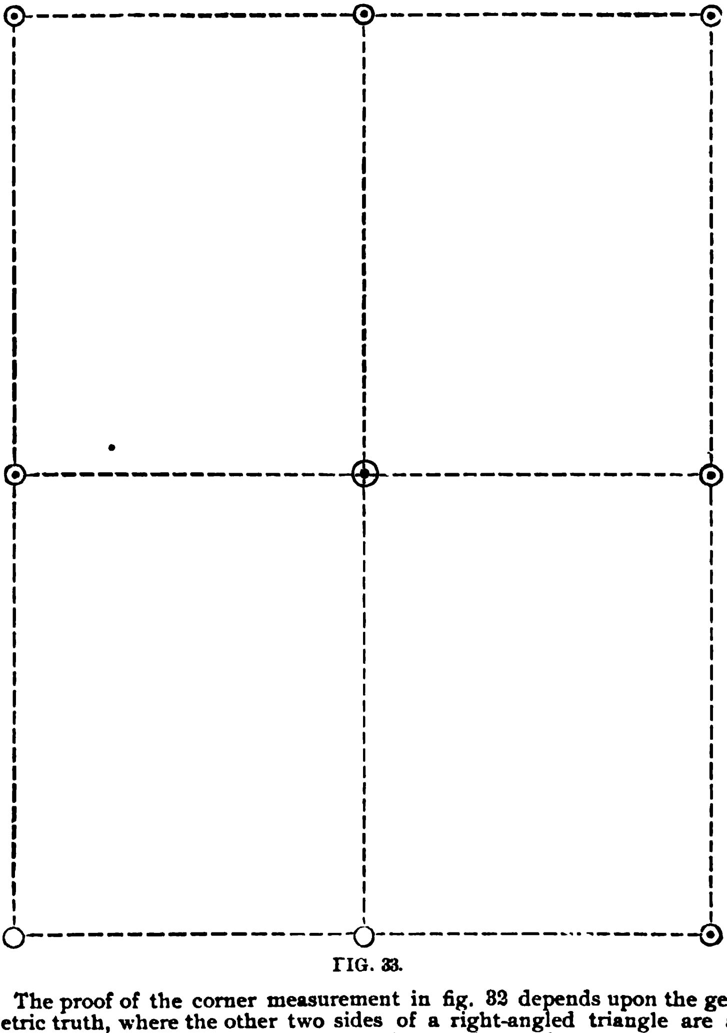


FIG. 33.

The proof of the corner measurement in fig. 32 depends upon the geometric truth, where the other two sides of a right-angled triangle are as three and four, the longest side or hypothenuse is equal to five; the same proportion holding true with all multiples of those numbers, or, mathematically, the sum of the squares of the base and perpendicular of any right-angled triangle is equal to the square of the hypothenuse; as in the present instance $6^2 + 8^2 = 10^2$, or $36 + 64 = 100$.

STAKING OUT.

Fig. 32 represents a simple method of setting two lines square with one another, as in laying out foundations, depending upon the geometric principle that the square of the hypothenuse in a right angled triangle is equal to the sum of the squares of the other two sides.

On one line mark off a point exactly, eight feet from the point of intersection, and on the other mark off six feet with equal carefulness. If the lines are square, the diagonal distance will be exactly 10 feet, if less, the enclosed angle is less than a right angle, and one line must be moved farther out ; if over 10 feet, the angle is obtuse and one line must be brought in.

Fig. 33 shows the four corner-pegs or stakes put in by the same method, as the half diagonal of the rectangle must measure 10 feet, and intersections of lines drawn through the points staked off in Fig. 31 (p. 45) must be 10 feet from the centre, if the lines are "square" or at right angles to each other.

Fig. 34 shows the method of laying out the lines of a foundation by means of cord lines stretched on *batter-boards*, as Fig. 35. First, one line, generally the front, is determined with reference to other machines, buildings or to a roadway, and stakes are driven, temporarily, to mark its ends. Two *batter-boards* are fixed at each corner, far enough outside to permit a clear passageway, each pair forming a right angle, this being tested by a large square or the method shown in Fig. 32.

A pair of batter-boards is next similarly fixed at each of the other corners, completing Fig. 34, and cord lines are

LAYING OUT.

stretched to mark off the building line; these last batter-boards are adjusted until all lines are quite square and occupying their proper positions.

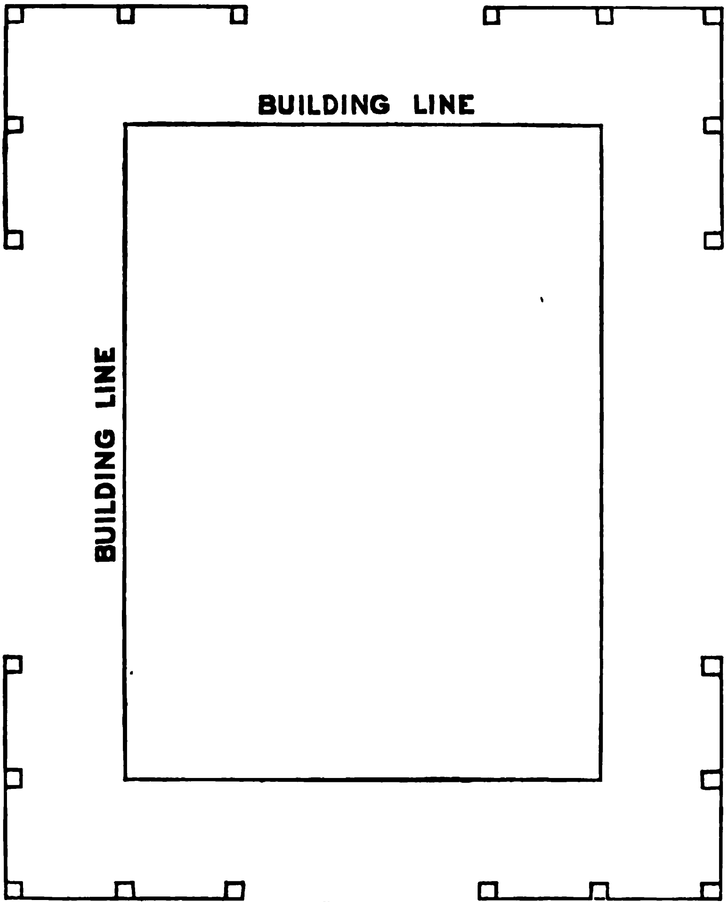


FIG. 34.

It is usual to fix two parallel cords in each direction to mark the boundaries of an excavation for foundations, etc., but for building walls, it is better to have a single line stretched on the *outside* face. A little thought will show that it is easily possible to line off projections, such as pillars and buttresses, by means of parallel cords.

Party walls are best marked off by a cord line stretched down their centre, while the work goes on equally each side.

To do the laying off most conveniently for a foundation or to set off centre points as for machines, etc., it is clearly preferable to put the batter-boards and cord lines well above the work, to give clear headroom, points being located by pointed plumbobs depending from the cord lines.

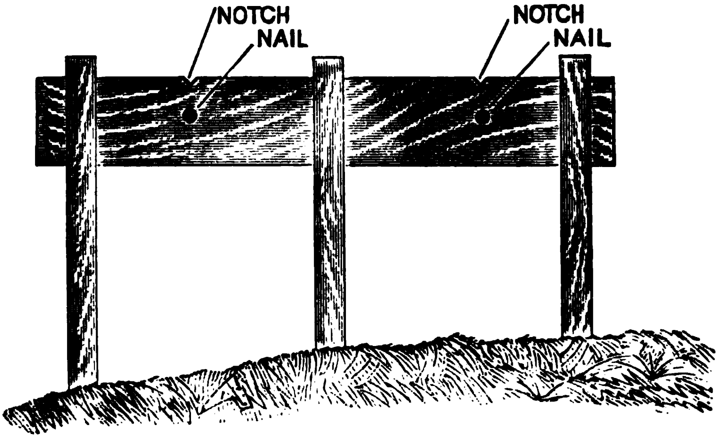


FIG. 35.

To obtain accurate alignment for walls or the limits of an excavation, it is customary to use *batter-boards* as in Fig. 35. These are stakes driven firmly in the earth, having a cross plank or batten as shown. The advantages of the batter board over the single stake are that it is less easily shifted, that by means of notches and nails the lines are defined with minute accuracy, and cords are easily replaced in case of breakage or necessary removal, while parallel lines are easily and rapidly laid out. Also, in cases of excavation, the batter-board stakes are easily knocked in, the board being adjusted with a spirit level, so as to follow the work as it proceeds downward.

To lay out a round foundation, put a nail or stake in the center, hook ring of tape line on this, and take half dimension of diameter on tape. Hold anything that will mark alongside of the tape and make a circle.

In draining and trenching, care should be taken to keep a foundation free from water. The mode for doing this depends upon the nature of the soil ; with gravel, water will run away easily, but it is advisable with other soils to have the trench for the footing walls cut some nine inches wider than the walls, so that the intervening space may be filled with gravel or stone chippings. The trench should slope away towards one corner, whence a pipe drain may remove the seepage.

Should the building be on the side of a slope, it is advisable to intercept the water on the high side. If a porous stratum overlies clay, it will be necessary to trench through the clay to a depth greater than that of the foundations and put in either porous pipes or tiles, or to fill the trench with small stones to lead away the moisture which may gather in a thin sheet over the impervious surface of the clay.

NOTE.—Foundations on clay need to be carefully watched as seepage of water washes the upper surface of the clay into mud and undermines the footings; again, if a mass of wet clay is allowed to press up against one end of a foundation, sliding may take place.

The essential instruments used in staking or laying out foundations, aside from those of the surveyors, will be found illustrated and described in the following pages.

Fig. 36 represents a double spirit-level for setting truly both vertically and horizontally.

The essential part of a spirit-level is a glass tube, closed at the ends, and having its bore larger in the middle than at the ends.

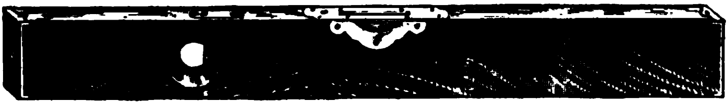


FIG. 36.

This tube is nearly filled with ether, or ether and alcohol, and the position of the "bubble," on which the value of the instrument depends, is naturally at the top in the middle of the length of the tube when it lies perfectly horizontal,—the bubble rising to the higher end when the tube is tilted.

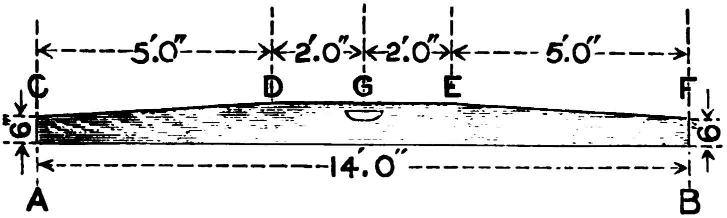


FIG. 37.

To ascertain the "truth" of an object with a vertical face, such as a pillar, the plain edge of the level is placed vertically against it, and the bubble across the staff is observed; to test a horizontal surface the level is laid on it, tube upwards, and note taken of the bubble in the lengthwise tube. The bubble keeping to one side of the horizontal tube denotes that that side is too high or the other too low; in the "vertical" tube the bubble lies at the end of the tube *opposite* to the *direction* in which the tested face is leaning.

INSTRUMENTS USED IN LAYING OUT.

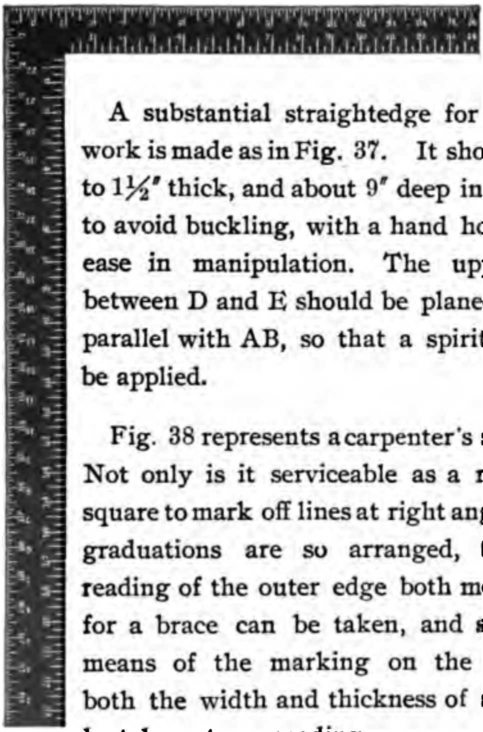


FIG. 38.

A substantial straightedge for setting out work is made as in Fig. 37. It should be 1¼" to 1½" thick, and about 9" deep in the middle to avoid buckling, with a hand hole at G for ease in manipulation. The upper surface between D and E should be planed and made parallel with AB, so that a spirit level may be applied.

Fig. 38 represents a carpenter's steel square. Not only is it serviceable as a rule or as a square to mark off lines at right angles, but the graduations are so arranged, that by one reading of the outer edge both measurements for a brace can be taken, and similarly by means of the marking on the inner edge, both the width and thickness of a plank can be taken at one reading.

There are also graduations to assist in calculating the contents of a board, and the length of a brace, etc: while by combining measurements read from the blade and tongue simultaneously any desired mitre can be laid off, as for an octagon or hexagon.

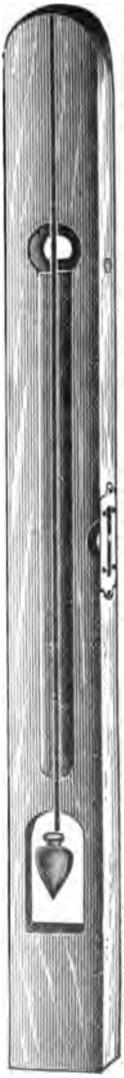


FIG. 39.

INSTRUMENTS FOR LAYING OUT.

Fig. 39 represents a combination of spirit level and plumb-bob, which is very convenient for mason's use or outside work generally. The grooves in the sides of the level are to enable the hands to get a better grip when holding it against a wall.

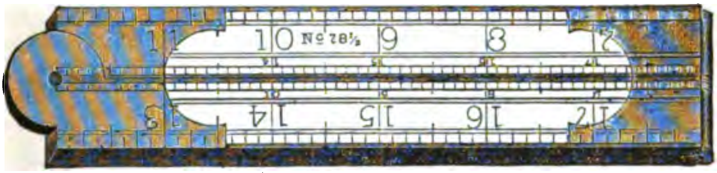
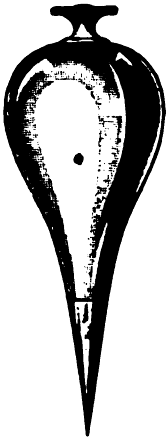


FIG. 40.

Fig. 40. The four-fold two-foot rule is generally made of boxwood, and is most convenient for carrying in the pocket to measure up work out of doors, or for purposes where fineness of measurement is unnecessary. Generally marked off to $\frac{1}{8}$ inch, with one or two folds marked to $\frac{1}{16}$ inch.



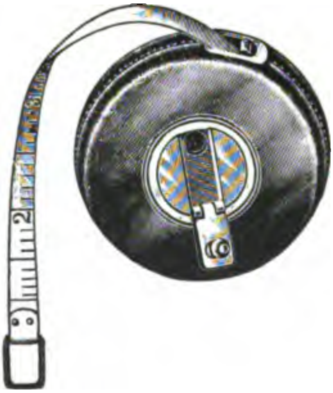


FIG. 42.

FIG. 41.

A good plumb-bob is shown in Fig. 41. It has a brass body filled with lead, and a steel point to insure absolute truth of measurement. The milled screw at the top is drilled through its

INSTRUMENTS USED IN LAYING OUT.

axis for the reception of the cord, which is passed through the hole, knotted on the end, the screw is then put in its place, thereby holding the plumb-bob quite centrally with the cord.

The measuring tape, Fig. 42, is most convenient for measuring out distances and areas. It is a narrow band of linen or flexible steel, graduated generally to feet, inches, and eighths on one side, and links and poles on the other, which is wound on a reel within a leather case. The usual lengths are 50 feet, 66 feet and 100 feet. For use around buildings linen tapes are preferable, as friction along masonry walls, etc., effaces the figures on a steel tape.

Surveyors' instruments are employed by engineers in laying out foundations of considerable size; they are also used in determining the center lines of shaftings and various principal machines in an extensive plant.

The leveling of the ground for creating the reduction of uneven surfaces to an even plane, and the notation of heights of the different portions of foundations is effected with remarkable ease and speed by sighting *through a leveling instrument* at one point to a *leveling staff* at another

The services of an experienced land surveyor are invaluable in laying out the lines of an extensive "works." Surveyors' instruments are many and costly owing to their nicety of construction—hence in great contrast to the simple device next described below.

A home-made level is made with a wooden frame as in figures 39 and 40, care being taken that the mitre at D is exactly at right angles with E, G, F, and that the hole for the plummet is halved by this same line. The notches at D serve to hold the cord of the plumb-bob.

INSTRUMENTS USED IN LAYING OUT.

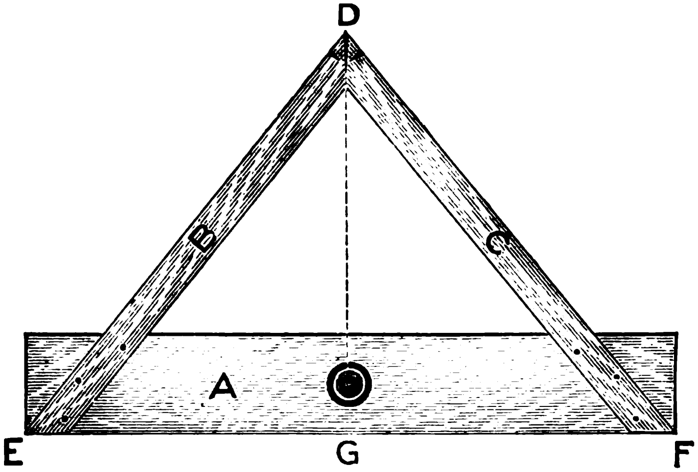
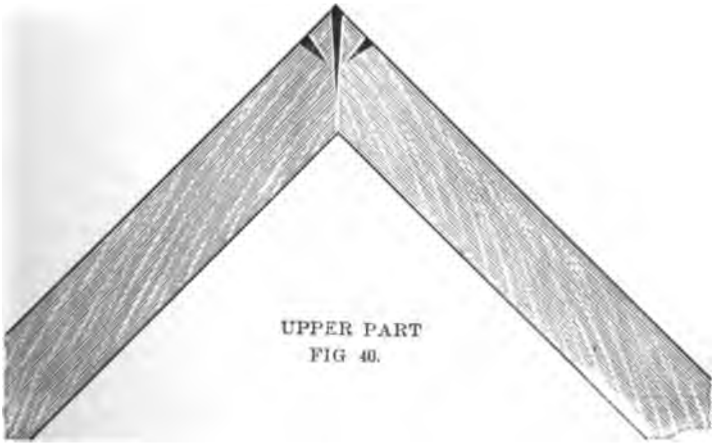


FIG. 39.



UPPER PART
FIG 40.

USEFUL TABLES.

AVERAGE WEIGHT OF 1 CUBIC YARD OF EARTHS, ROCKS, ETC.

	lbs.		lbs.
Dry peat	850	Clay	3250
Wet peat	1650	Rough water gravel	3800
Top soil	2240	Grey chalk	4000
Common earth	2700	Sandstone	4300
Sandy loam	2700	Shale	4400
Mud	2800	Limestone	4500
Marl	2900	Granite	4700
Wet sand	3100	Trap	4700
Common gravel	3100	Quarried rock	4250

SLOPES OF SIDES OF EXCAVATIONS.

MATERIAL	RATIO OF BASE TO HEIGHT
Clay, well drained	1 to 1
" wet	3½ to 1
Earth, dry	1¾ to 1
" moist	1 to 1 to ⅞ to 1
" very wet	3¼ to 1
" rammed or punned*	½ to 1 to ⅓ to 1
Gravel, clean	$\frac{9}{10}$ to 1
" with sand	2 to 1
Sand, fine dry	⅓ to 1 to 1⅝ to 1
" wet	2 to 1
Shingle, loose	1¼ to 1

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*In England, the act of ramming earth into a hole is called "punning," and the ramming tool is known as a "punner."

EXCAVATING.

The word "excavating" has been sufficiently defined in the glossary prefixed to this work. In every building specification made by a competent architect or engineer the details of the excavation form an important part. There is hardly a class of engineering construction into which excavation of earth or rock does not enter to some extent.

A few pages follow of illustrations and text relating to the different operations which are required for executing work of excavation in either earth or rock; the intention is also to describe later on a few of the various implements and machines used.

Several earths and similar substances are described below.

Spoil is waste material removed in cutting, mining or excavating. A *spoil-bank* is the place where mining refuse or excavated earth is deposited. This is the opposite of a *borrow-pit*, which is a place, as a bank of earth, where material is obtained that is to be used as filling elsewhere.

Land is the solid substance composing the material part of the earth, considered as a whole, especially the exposed surface of the earth as opposed to the seas, or considered in reference to its use as coal-land etc.

Ground is the firm solid portion of the earth at and near its surface; also the disintegrated material of the surface, hence a pavement or floor or any supporting surface.

Site is a plot of ground suitable or set apart for some specific use, or that has been so occupied as a site for an emergency plant.

VARIOUS EARTH MATERIALS.

Alluvial soils are composed of sand and mud—the sedimentary deposits of bygone rivers.

Earth is soil, distinguished from rock; any natural soft soil.

Mould is a rich soil, composed almost entirely of decaying vegetable matter.

Soil so called is the upper surface of the earth, consisting of fine mineral or earthy substance, pulverized from the rocks by natural forces, together with a more or less large admixture of vegetable or other organic matter, arising either from the natural decay of vegetation or the artificial process known as manuring.

Subsoil is the stratum immediately beneath the soil, and partaking largely of its characteristics, as it is in a measure subject to the same influences.

Loam is a soil chiefly composed of sand, clay and carbonate of lime; with more or less of oxide of iron, magnesia and various salts which with a proportionate part of decayed vegetable and animal matter give it its fertility. In excavations loam is very often separated from other earth and preserved for after use. The primary meaning of the word is slime or mud.

Sand is composed of siliceous or calcareous material ground from rocks by the action of weather and watercourses. Sand obtained from rivers and lakes is termed "*sharp sand*" because of its angular nature. *Sea sand* on the contrary has its grains rounded by attrition, and consequently does not bind so easily.

Quicksand is sand mixed with so large a quantity of water that it is semi-fluid, and can neither bear weights upon its surface, nor retain its place during excavation.

VARIOUS EARTH MATERIALS.

Turf is composed of matted grass-roots and other matter forming a peaty crust or sward on the surface of the soil.

Mud is the finest state of precipitated matter from rivers or the sea, being the particles of rocks ground down so fine that the water cannot carry them further.

Gravel is composed of broken down fragments of original rocks, ground into pebbles by the action of seas and rivers, and deposited either on ancient beaches or as bars in former river beds.

Clay is formed of the harder rocks, broken down and disintegrated by the weather, watercourses, and other forces of nature. Pure clay is a hydrated silicate of alumina, being found as such where originating from decomposed granites and other feldspar rocks. Usually however, sand or other siliceous material is mixed with it. All clays contain not only hygroscopic water which can be driven off by moderate heat, but also water in chemical combination to which the material owes its plasticity. When heated or baked to such an extent as to expel this constituent water, the clay becomes permanently hard, and its plasticity cannot be restored.

Chalk is rock formed from the deposited fossil remains of countless marine animalculæ, shell-fish and sea urchins. Its chief constituent is carbonate of lime. Chalk is soft, easily crumbled, and when purified is used for purposes of marking or writing.

Shale is clay or mud hardened into rock under the pressure of the overlying strata.

VARIOUS EARTH MATERIALS.

Hard pan is the appropriate name of a dense, almost inpenetrable crust of clay, or compacted gravel, often underlying a fairly fruitful ground. It is the soil turning to rock. In mining, it is defined as a layer of firm detritus under soft soil.

When first excavated, all materials will increase in bulk, but after lying a while, will with the exception of rock, shrink until they occupy less space than when originally in the earth.

The shrinkage of various materials has been estimated as follows:—

Gravel	8	per cent.
Gravel and Sand	9	"
Clay and Clay-earth	10	"
Loam, and light sandy earth	12	"
Loose vegetable soils	15	"
Puddled Clay	25	"

The carrying power per square foot of several surface materials is given below. The figures are approximate.

Rock, hard on native bed	250	Tons
Ledge Rock	36	"
Hard pan	8	"
Gravel	5	"
Clean Sand	4	"
Dry Clay	3	"
Wet Clay	2	"
Loam	1	"

EARTH EXCAVATION.

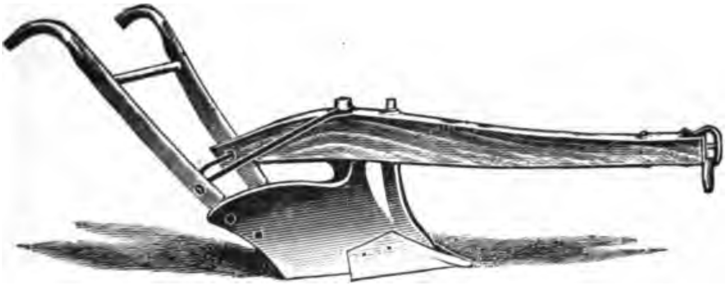
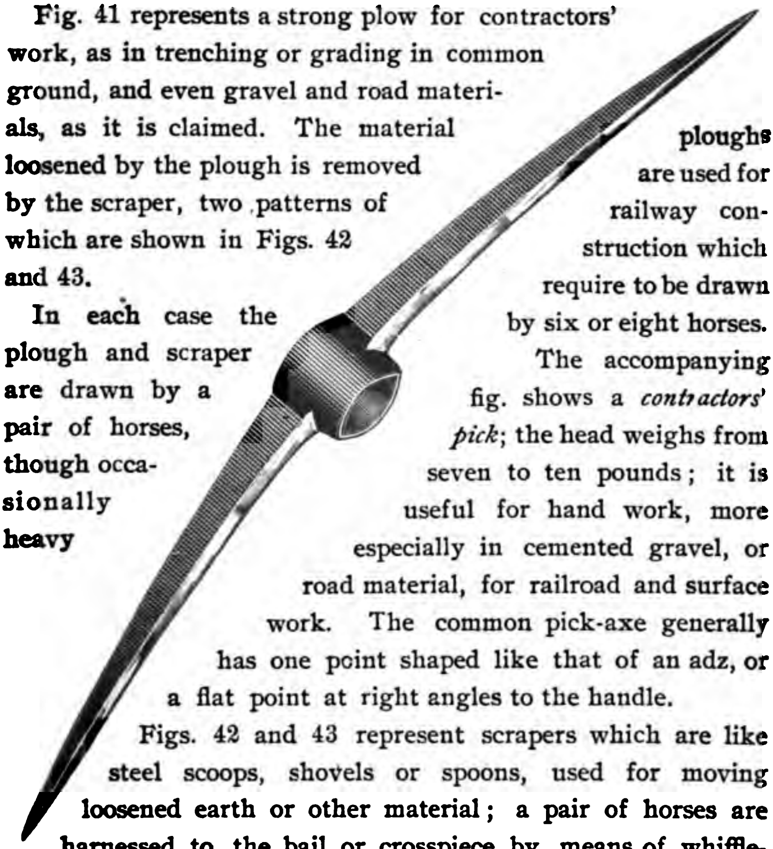


Fig. 41.

Fig. 41 represents a strong plow for contractors' work, as in trenching or grading in common ground, and even gravel and road materials, as it is claimed. The material loosened by the plough is removed by the scraper, two patterns of which are shown in Figs. 42 and 43.



In each case the plough and scraper are drawn by a pair of horses, though occasionally heavy ploughs are used for railway construction which require to be drawn by six or eight horses. The accompanying fig. shows a *contractors' pick*; the head weighs from seven to ten pounds; it is useful for hand work, more especially in cemented gravel, or road material, for railroad and surface work. The common pick-axe generally has one point shaped like that of an adz, or a flat point at right angles to the handle.

Figs. 42 and 43 represent scrapers which are like steel scoops, shovels or spoons, used for moving loosened earth or other material; a pair of horses are harnessed to the bail or crosspiece by means of whiffletrees, and the scraper is then drawn over the ground, scraping up the surface like a spoon. The tool has a capacity ranging from three to seven cubic feet, and is guided by the driver, who dumps the contents at the required spot by manipulation of the handles and steering the horses so as to tip the scraper.

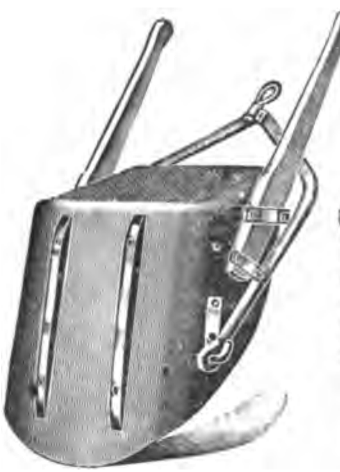


FIG. 42.

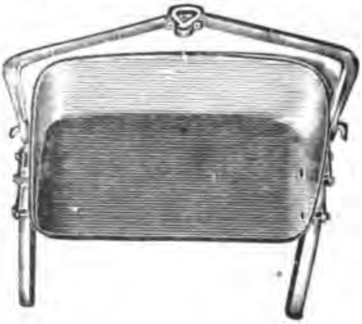


FIG. 43.

A "shore" is a beam, used as a prop, as against the side of a building. In earth excavation one of the first points is to take care of the shoring, i. e., have the planking and timber so placed that it will prevent the banks from caving in. The frame shoring (see figs. 48 and 49) must be put in the hole as soon as the excavation *is that depth that the soil is going to fall in.*

NOTE.—"Put planks behind the frame and drive them down with a wooden beetle as far as possible. Observe when digging that you always dig on the outside line of the hole first, say about two feet deeper than the centre; this gives you a chance to lower the frame and planks and makes the work easier. As in many cases where the soil is very soft and water appears at no great depth, have a place kept lower at all times to put a pump in or bale out (see figs. 45 and 46). Incidentally it may be remarked that the soil excavated must not be placed too close to the opening. Enough room should be left at the side to receive the foundation materials, as well as a place for mixing mortar or concrete."—*Harms.*

Fig. 44 shows a *hand pump* useful for keeping water down in excavations or for supplying water for masons' use.

A substantial *galvanized pail* with strong lugs and bail is shown in fig. 45; useful sizes are twelve and fourteen quart buckets.

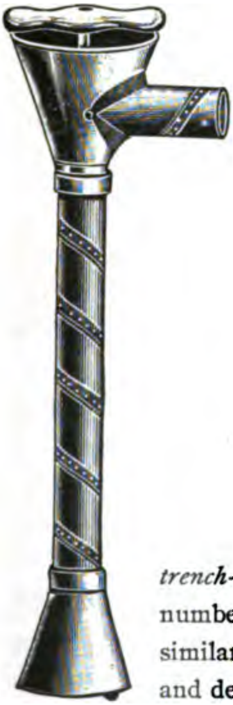


FIG. 44.

FIG. 45.

Machinery used in earth excavation comprises among others crane-worked grabs, (also termed *steam shovels,*) *steam navvies* and the *trench-cutter*. This latter machine has a number of buckets working on a ladder similar to the well-known ladder dredger, and delivers the excavated spoil at one side. It is continuously used in making trenches for pipe laying, sewers and the like; it is made in two patterns, one in which the ladder is hung at the side of the carriage for cutting an indefinitely wide trench, and the other having the ladder fixed between the wheels of its carriage which bestride the trench it is desired to cut.

EARTH EXCAVATION.

One excavator using pick and spade, will keep busy two shovellers and two barrow-wheelers in compact earth, but only one of each on ordinary clay.

A shoveller will throw each shovel full of earth six to ten feet horizontally, or four to five feet vertically.

In an eight hour day a good excavator will dig and throw into a barrow six to eight cubic yards of common ground, about five cubic yards of firm clay or compact gravel, or from two and one-half to four cubic yards of hard ground where the pick has to be employed. One excavator to each six feet of face of cutting is as close as is desirable.

Wheelbarrows holding $\frac{1}{10}$ cubic yard, are the most economical means of transport where the distance does not exceed 100 yards. Barrow runs should be provided, as they increase the capacity of the wheelers by at least 50 per cent. These consist of 12″ × 3″ planks, mounted on box horses where it is desired to give an inclination. The gradient should not be steeper than one in twelve, unless assisting gear, such as hauling ropes, is provided. Efforts should be made to keep the slope down to one in thirty. A barrow run is reckoned as about twenty-five yards, each foot of rise being estimated as equal to two or three yards extra run.

Tip carts drawn by one horse are much used in transporting earth, but with them as with barrows it is more economical to

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NOTE.—*Portable railways* have rapidly displaced much of the earlier appliances. These miniature lines, having a gage of 2 feet, are laid with rails weighing 14 to 18 lbs. to the yard, and are keyed up to steel crossties at the proper gage preparatory to laying. As the sections are only about 13 feet long, two men can easily carry them from place to place where the loose parts are connected together to the desired position, only requiring the tightening of a few bolts to unite them with the track.

provide good temporary ways, as the hauling power will be doubled thereby. Assuming good ways, a cart can hold ¾ cubic yard of earth, or say 1 ton.

In dealing with the removal of earth from long and narrow trenches, as in the case of foundations, most of the foregoing methods cannot be used.

A rectangular bucket, narrow in comparison with its length, as Figure 47, is designed for this special service, and is intended to be worked by a crane or hoisting engine.

A method, modified from a mine-prospector's device, is as follows. A trestle is erected astride the trench, having a runway *rising* slightly to the dump. A four-wheeled carriage rests on this runway, and is locked in position by a catch over the trench; from this carriage depends the pulley for the bucket-rope. A horse travelling horizontally pulls the bucket vertically; as soon as it is fully hoisted it disengages the carriage, and the horse pulls carriage and all to the dump. As soon as the bucket or skip is emptied, and the horse starts to return, the carriage runs back along the runway by its own weight, and becoming automatically locked again, the bucket descends into the trench once more.

If a portable railway can be used, it is also advantageous in working on a slope, to have the team of horses travel on the level, pulling at a rope led around pulleys and fairleads.

In the paragraphs succeeding, a b c is condensed information, which would require a large volume to thoroughly present. They are given as "pointers" to the student.

(*a*.) *Removal of the earth in layers*:—a suitable mode for large excavations where the earth is easily won, and a large number of men can be got to work at one time.

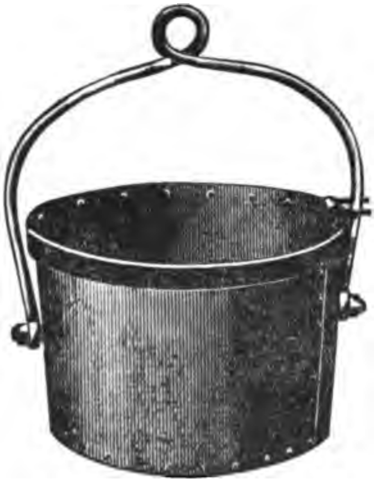


FIG. 46.

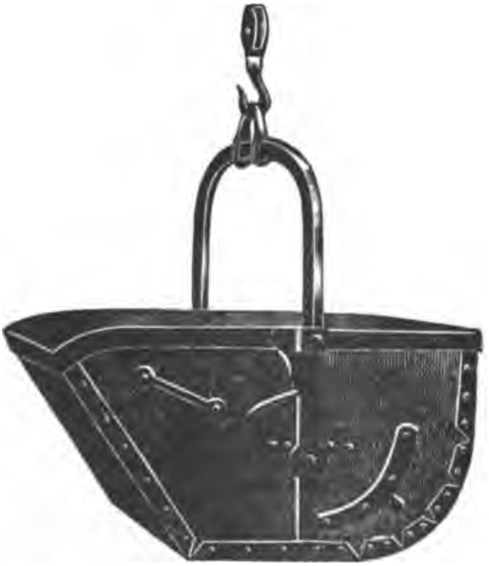


FIG. 47.

EARTH EXCAVATION.

(*b.*) *Terracing*:—that is, removal of the material in benches, each of which has its own transportation way. This method is suitable for cutting away the side of a slope.

(*c.*) *Long face working*:—a narrow cutting is taken down at once to the formation level for the whole length of the work, serving for drainage and transportation-way, and the ground is attacked at each side. This makes an advantageous method of dealing with rock, as blasting etc., can be carried on at several different points on both sides.

A mining tub or bowk is shown in fig. 46. These are used to hoist minerals or ore from excavations; also to remove spoil. The sizes vary from 6 to 32 cubic feet in capacity. The bail is fitted with a latch to prevent the tub from tilting as it is being raised.

The illustration on the first page of this book represents a side-tip or dump wagon as used by contractors or miners, for conveying excavated material. The car tips or dumps to either side, and automatically returns to its vertical position when empty. The tipping action is controlled by the lever seen at the front of the frame, and a hand screw fixes which side the tray shall tip.

Fig 48 shows the methods adopted in timbering trenches. *Poling boards* about three feet long, one to one and one-half inches thick, and seven to nine inches wide are used to retain the soil, a fresh row being added at each three feet of depth; in excavations below six feet one row of planks four or five feet long would suffice. *Waling boards*, or strips run the whole length of the trench; they should be nine by three inches and are generally placed, one near the surface of the ground, and another at the centre of each row of poling boards.

Struts or cross timbers abut on the waling boards at each side, and hold the timber lining firmly against the walls of the trench. Struts are from four to six inches square, depending upon their length and the pressure.

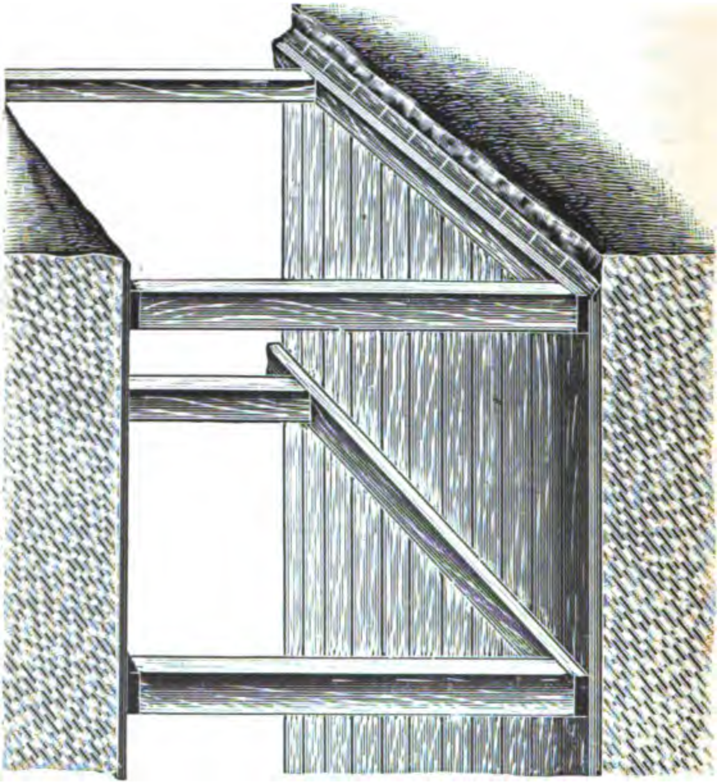


FIG. 48.

Sheet piling is also resorted to should there be much water in the soil; in this case the piles, properly squared are driven side by side as closely together as possible, with a tongue or feather fitting into groves in each, similar to matchboarding.

Fig. 49 shows the frame of poling boards, waling planks and struts *for shoring a large excavation*, thirty-two by twenty-four feet in soft soil.

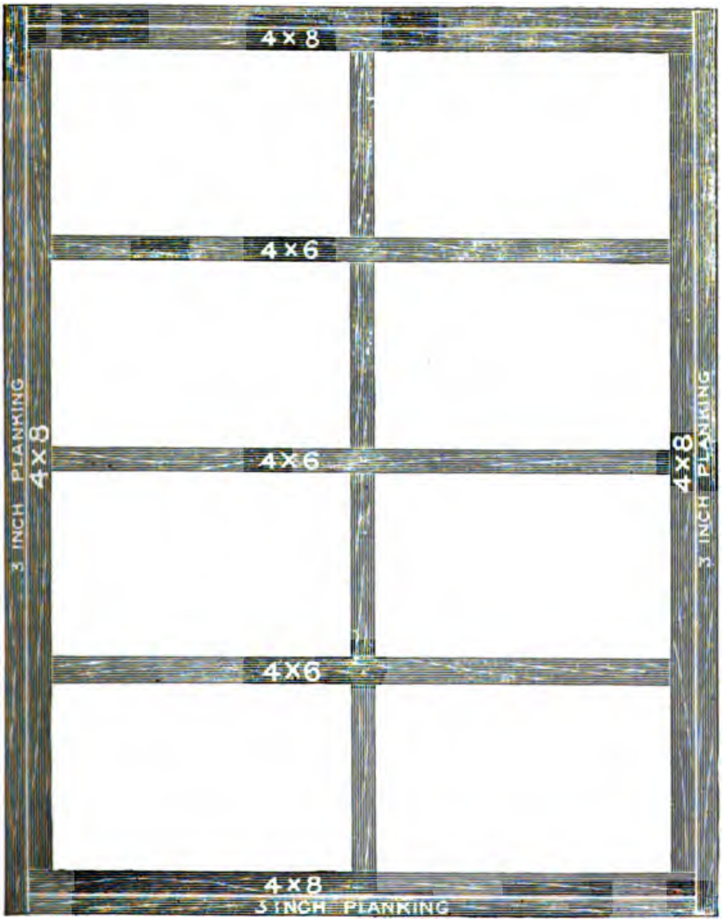


FIG. 49.

In this case the sides will be sustained by 3 inch planking almost close enough to constitute sheet piling.

SHORING AND UNDERPINNING.

Shoring is frequently resorted to in excavating foundations; this means placing timber struts obliquely against the walls of a building to support it, should it be in danger of falling, or whenever alterations are being made to its base. Naturally, if an excavation is carried close to the walls of an existing structure, the pressure will tend to force the footings sidewise, and a collapse is threatened.

Rectangular holes are cut in the upper part of the wall to be supported, in which are placed timber *needles* six inches square and a foot long, projecting seven or eight inches. On these needles is placed vertically a stout plank, 9″ x 3,″ its length depending upon the height of the building. Shores are arranged in tiers of three, abutting on one end upon a footing block of wood, and at the other upon the upper, middle and lower needles through each plank. A customary size for these struts or shores is 12″ x 6.″ A cleat is usually nailed to the plank on the upper side of each needle to reinforce it, and one inch planks are nailed to the sides of each tier of shores to hold them together.

Underpinning is a solid structure introduced temporarily or otherwise beneath the foundations of an existing building to support them in case of alteration or excavation beneath the footings.

A favorite method of underpinning is to build piers in pairs, one each side of the threatened wall, to the desired height from solid ground. The wall is pierced for rectangular wooden beams, termed "needles," which rest with one end on each pier of a pair. Wedges being driven in under the needles, the weight of the wall is transferred from the footings to the piers.

Rock **is a mass or aggregation of mineral matter, generally composed of two or more minerals; there are over six hundred minerals classified by geologists but less than a dozen of them constitute the principal commercial rocks. Quartz, feldspar, mica and hornblende with a few others make most of the *igneous rocks*, while silicates, carbonates and sulphates, of the metals calcium and magnesium form the principal simple or *non-compound rocks.***

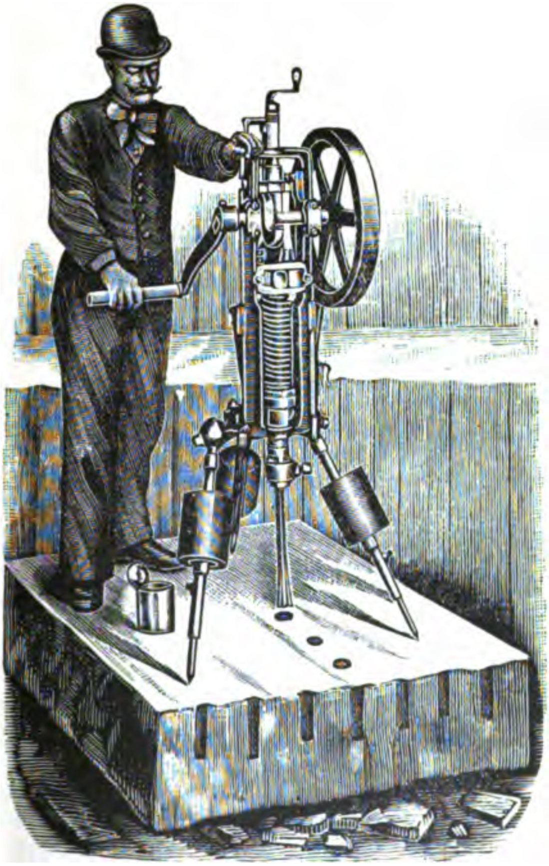


FIG. 50.—See page 77.

ROCK EXCAVATION.

While minerals are held to be inorganic bodies, possessing a more or less definite chemical composition, and a characteristic crystallization or geometrical form, the rocks derived from them may differ widely as regards chemical composition, and generally have no definite shape or form.

This definition covers alike basalt or chalk, pumice stone or clay, and *the term rock denotes hard mineral matter* only, and does not include the unconsolidated material near the surface of the earth. Some rocks are simply chemical deposits from precipitation or evaporation in prehistoric seas, as rock-salt or gypsum. The further weathering of the materials broken down from the rocks, and the combination therewith of decayed vegetable and animal matter, produces the soil which grows all our food.

A brief description of the principal rocks encountered in various excavations follows:—

Bluestone is of the nature of clay—a sandstone, quarried in the valley of the Hudson River (U. S. A.), and used for building purposes, flagstones, etc.

NOTE.—Most of the primary rocks are compounds of two or more minerals melted together, hence termed *igneous*, and constitute either *plutonic* rocks, as granite, formed at a great depth under pressure ; or *volcanic* rocks which have flowed from a crater over the surface similar to lava. Again, other forces, wind, rain, frost, flowing water and the waves of the sea, have acted upon these primary rocks, and the disintegrated materials have accumulated and consolidated into fresh combinations. The crystalline granite has decayed into clay, the quartz rocks have broken up into boulders, gravel, sand, and mud. Other strata having been deposited upon these, the overlying weight and naturally contained cementing material have changed clay into slate, gravel into pudding stone, sand into sandstone, and mud into shale. These are termed *sedimentary* or *stratified* rocks. Other formations are derived from the deposition of animal remains, such as chalk and coral, while masses of vegetation form first peat, and then, under time and pressure, coal.

VARIOUS ROCK MATERIALS.

Brownstone is a dark colored sandstone found in the valley of the Connecticut River (U. S. A.), and is much used for building purposes.

Freestone is a term applied to all sandstones that can be freely worked in any direction; also by extension to other good building stones.

Granite is a hard crystalline rock of granular structure, formed by the fusion together of feldspar, mica, and quartz. It is an eruptive or plutonic rock, formed at some depth below the surface. Granite is hard to work, possesses great strength and durability, but cannot have fine carving executed on it. One noteworthy point is that granite can be quarried to almost any size. It varies in color from grey to red, frequently being handsomely mottled, and is generally capable of receiving a high polish.

Lava is molten rock which flows from volcanoes during eruption and becomes cooled and solidified. Lavas vary greatly, but the usual form is a dark colored glassy substance in which crystals are imbedded.

Limestone is the name of any rock of calcareous origin, or which consists principally of carbonate of lime; formed either by chemical precipitation of calcic carbonate or from the deposition of animal remains, a good modern instance of which can be seen in coral reefs. Building limestones are of three classes,

---

NOTE.—Limestone usually contains coral shells and fossil remains of marine animals, usually more or less broken. The color is grey or light blue, though occasionally buff color. Oolite limestones polish beautifully. All limestones are destroyed by fire, and the smoke of cities is apt to discolor them.

oolite, in which the lime particles are in small rounded grains like the roe of a fish ; *magnesian* limestones, containing at least ten per cent of magnesium; and *dolomite*, in which under heat the limestone has been so altered or metamorphosed that magnesium carbonate has to a great extent taken the place of the carbonate of lime.

Marble is limestone that has become crystallized under heat and pressure ; it is capable of receiving a high polish. Statuary marble is indeed so crystalline that its fracture resembles that of loaf sugar. The beautiful colorings and markings of marbles are generally due to the presence of iron.

Porphyry. Anciently this name applied to a dark crimson or purple rock through which were scattered crystals of feldspar. Modern usage has given the term to a dark colored, fine-grained rock of very hard texture through which are disseminated distinct crystals of some mineral. These handsome stones are much used for pillars and ornamental work.

Sandstone is a stratified rock formed from deposited sand under the pressure of the overlying strata, and bound together by some cementing material, upon which depends the color and durability of the stone. If this binding material is a silicate, the rock is light colored, durable and hard to work ; if the cement is an oxide of iron, the stone is dark or brownish in color, and not too hard to work readily. Carbonate of lime gives a grey stone that is soft and easy to work, but which weathers badly because the lime dissolves in water ; while clay is even worse, as it absorbs water, hence exposing the stone to risk of injury from frost.

Schist is any rock that has been so changed by heat and pressure that it has a tendency to *foliate* or split off in thin sheets. Naturally bedded shale is in layers or *laminated*, and slate, metamorphosed, can be easily split; the splitting of schist is different, and seems due to its mica planes.

Slate is clayey material hardened into rock under pressure like shale, but differing from it in this, that it has been exposed to the changing action of heat and lateral pressure so that the grains of which it is composed have been re-arranged at right angles to the bed in which they were deposited.

Trap is any unclassified eruptive rock, similar to basalt; it derives its name from the step-like terraces into which it is usually formed.

Whinstone is a hard quartzoze sandstone, so called because it is suitable for making hand mills.

Rock excavation calls for the use of different appliances from those used in earth work, consequent upon the greater hardness and coherence of the material.

Figure 50 is an illustration of *a portable rock drill*, intended to be worked by hand power. The whole is supported on three swivelling adjustable legs, so as to be easily and firmly fixed in any desired position, while heavy iron weights are suspended from the tripod legs, to keep the centre of gravity low and thus hold the drill steady.

The tool bar is lifted to the proper height by cams on a rotary shaft, which is turned by the operator, the cams having two or three points, to give that number of blows per revolution. When released by the cams, the tool bar falls with great force, augmented by a powerful spiral spring shown in the engraving,

TOOLS FOR ROCK WORK.

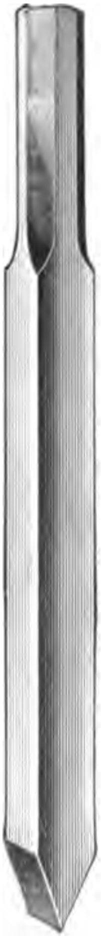


FIG. 51.

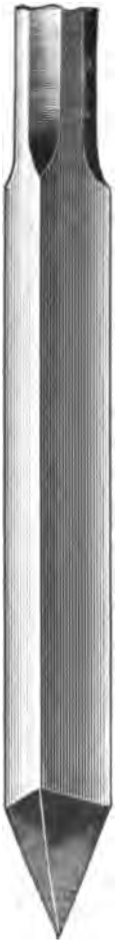


FIG. 52.

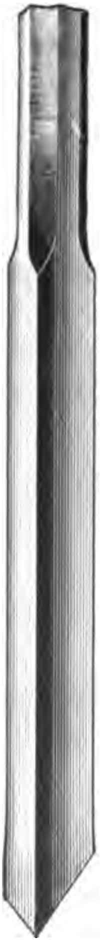


FIG. 53.

TOOLS FOR ROCK WORK.

The bar is automatically turned, so as to make a round hole, by a lever which engages with a spiral wormwheel on the bar during the up-stroke, this mechanism being concealed within the box shown at middle of the frame. The feed is also automatically regulated in accordance with the rate of penetration, although capable of hand adjustment when desired.

Fig. 51 represents a *wedge point crowbar*, the point serves for use as a chisel in dealing with masses of rock.

Fig. 52 represents the *lining crowbar* frequently used as a quarryman's *gad* to make holes in masses of rock or in cemented gravel, etc.

Fig. 53 is the more usual *pinch point bar* used to pry off lumps of stone or for general leverage purposes.

These three tools can be seen at any time in use by excavators working in the public thoroughfares for removing the concreted mass of the road bed.

Fig. 54 shows a *striking and hand-drilling hammer* of the pattern known as Oregon Striking. Different workmen use various weights, but from 3 to 5 lb. weight is generally used for single handed drilling, while 6 to 9 lb. hammers are used for double handed drilling, especially where, as is frequently the case in the United States, there are two hammers to each bar.

Fig. 55 is a stone sledge used in breaking up lumps of stone, etc.

In excavating rock, much depends upon whether the stone is loose, bedded or massive.

TOOLS FOR ROCK WORK.

If the rock is *loose* or decayed, one or another of the crowbars illustrated in figures 51-53 may be used to pry pieces off, and fragments which are too large may be broken up by the stone sledge, shown in Figure 55,

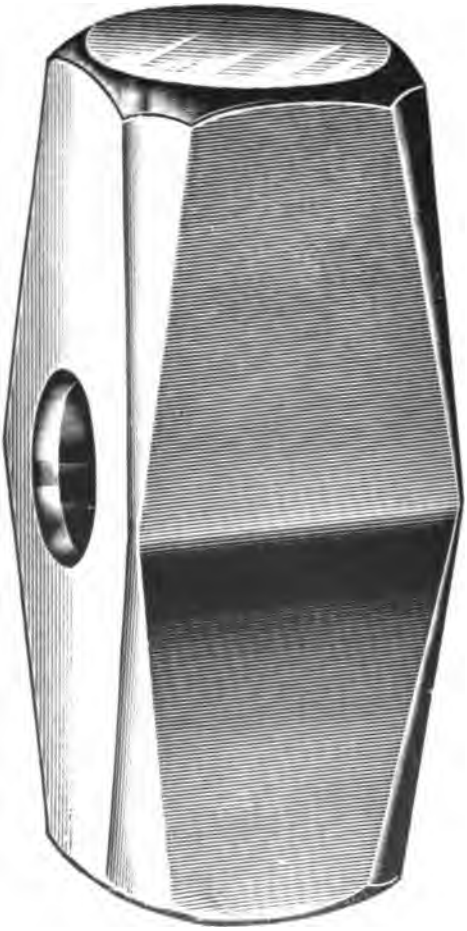


FIG. 54.

ROCK WORK.

If the stone is *bedded*, that is, shows distinct lines of stratification or formation in layers, together with joints, or breaks at right angles to the bed, good work can be done with wedges driven into the seams. The "gad," a pyramidal wedge, may be used to punch holes along these natural cleavage lines, and into the series of openings thus made, are put plugs and "feathers."

The feathers consist of two short pieces of half round steel turned over at one end to prevent them falling into the hole; they are inserted in the opening made by the gad, and the plug, which is simply a wedge, is driven down between them; the strain of a number of these wedges along the bedding line breaks out large masses of stone.

When the stone is too firm or uniform to be got out by the foregoing methods, drilling and blasting must be resorted to. To prepare the rock for the footings of foundations, the loose and decayed portions should be cut away regardless of the trouble and expense.

"Having drilled to the desired depth, the explosive, which is usually pebble powder or dynamite, is placed at the bottom of the holes, care having been taken to keep them dry, by baling or waterproof lining. Each hole is closed by tamping or clay, well rammed in, confining the force of the explosion in the desired direction. The charges are ignited by means of waterproof fuses led to a detonator within each cartridge. The customary method is to lead slow burning fuse, which has its rate of combustion marked on each coil, from a safe spot to the holes, all of which are connected by a train of instantaneous fuse, so that all explode simultaneously. Occasionally the electric current is used over two wires to each detonator from a main lead. Afterwards, gad, wedge and crowbar are brought into play, and the masses of rock loosened by the explosion are pried out for removal."

TOOLS FOR ROCK WORK.

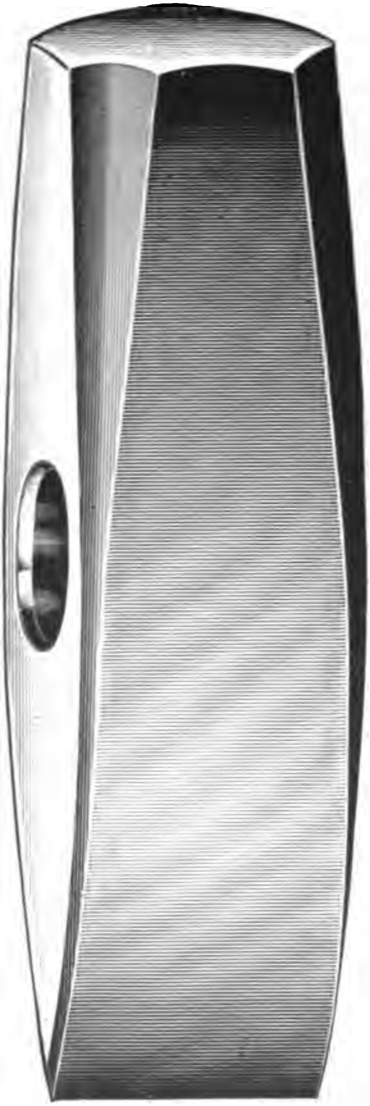


FIG. 55. See page 79.

TOOLS FOR ROCK WORK.

In *hand drilling* either the "jumper" or drill is used, each having a round chisel point; but while the former, being used in a more or less vertical position, is enlarged in the middle to give force to the blow as it is jumped up and down, the latter is struck on the head by a hammer like that shown in figure 54, wielded either by the driller or his helper.

Drilling machines are much used, and even if the amount of drilling to be done is small or infrequent, a hand power machine, as figure 50, soon repays its cost, as it operates nearly five times as fast as hand drilling.

The *steam drill* has much of its mechanism similar to the hand power machine, but the drill bar is connected to the piston of a steam cylinder, thus increasing the number and force of the blows. Where much drilling has to be done on the surface, the usual plan is to install a number of drills, taking steam from a central boiler through lines of flexible metallic hose. *In confined or underground workings it is customary to substitute compressed air for steam.*

Fig. 56 is a *rock-lifter*, by means of which one or two men "pumping" on the end of a 10 or 12 foot ash lever, can lift heavy rocks, pull tree-stumps, etc. A stirrup hanging from the end of the lever engages with the teeth of a ratchet wheel on the block axle, so that, with each stroke, the wheel is pulled around two or three teeth, and the sprocket wheel shortens the "bight" of the chain, thus exerting an accumulated force in lifting. The ratchet wheel is prevented from slipping by means of a pawl or "detent" on its opposite side.

TOOLS FOR ROCK WORK.

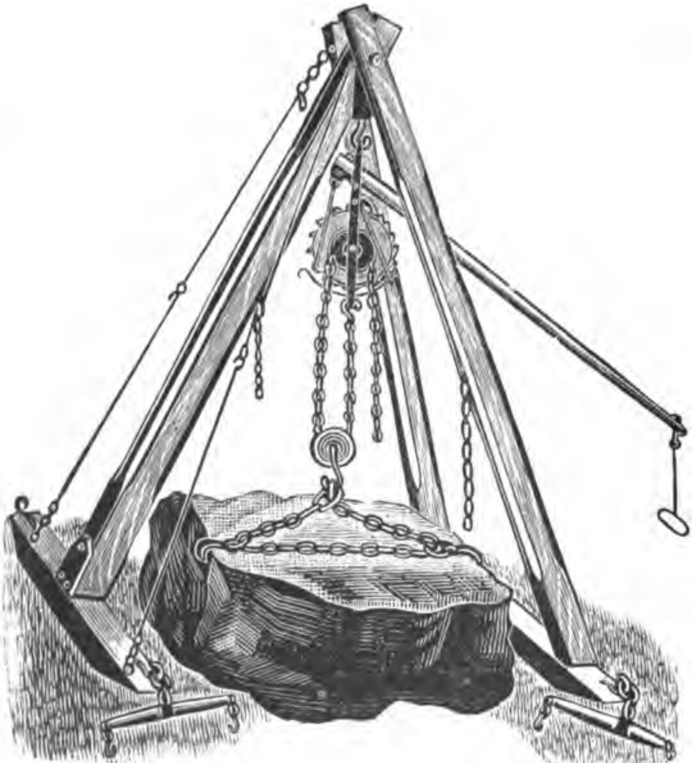


FIG. 56.

PILING AND GRILLAGE.

A *pile* is a heavy beam, frequently the rough trunk of a tree, pointed at the end, and driven into the ground to support some superstructure, such as a wharf, pier, or building.

A *grillage* is a heavy framework of timbers connecting the tops of the various piles and serving to support a foundation.

A *false pile* is a lengthening piece spliced on to a driven pile.

A *screw pile* is fitted with a screw disc or shoe of cast iron, similar to the cutting nose of an auger; these piles may be of wood, wrought or cast iron, and are sunk by manual power acting on capstan bars in the head of the pile. A water jet is frequently used to facilitate the sinking of screw piles in hard ground.

Gauge Piles are those driven at regular and measured intervals, to which are fastened horizontal pieces of wood serving to guide intermediate or *filling* piles.

Caps are connecting beams on the heads of piles.

Pile Hoops are rings of wrought iron fastened around the heads of piles to prevent their splitting or brooming under the blows of the ram or hammer. A good size for hoops is 3″ x 1″.

Iron Cylinder Piles are cast iron rings bolted together and sunk by their own weight in soft ground, to serve as piles, the material inside being excavated by hand, or if much water by means of a grab. This method is sometimes used in connection with a water jet at the head of the pile, the core being pumped out as slurry. The interior is then filled with cement or concrete.

FOUNDATIONS.

In making foundations, more especially in soft ground it is frequently expedient to use piles to support the footings. Their use resolves itself into two main branches, (1) when there is a lower stratum of hard ground or rock, in which case the pile acts as a pillar supporting the structure, (2) where the ground is soft throughout, and the support of the piles is obtained from friction of their sides with the soil.

The piles are forced into the ground by means of a pile-driver such as shown in Fig. 57, which consists of a wooden frame sup-

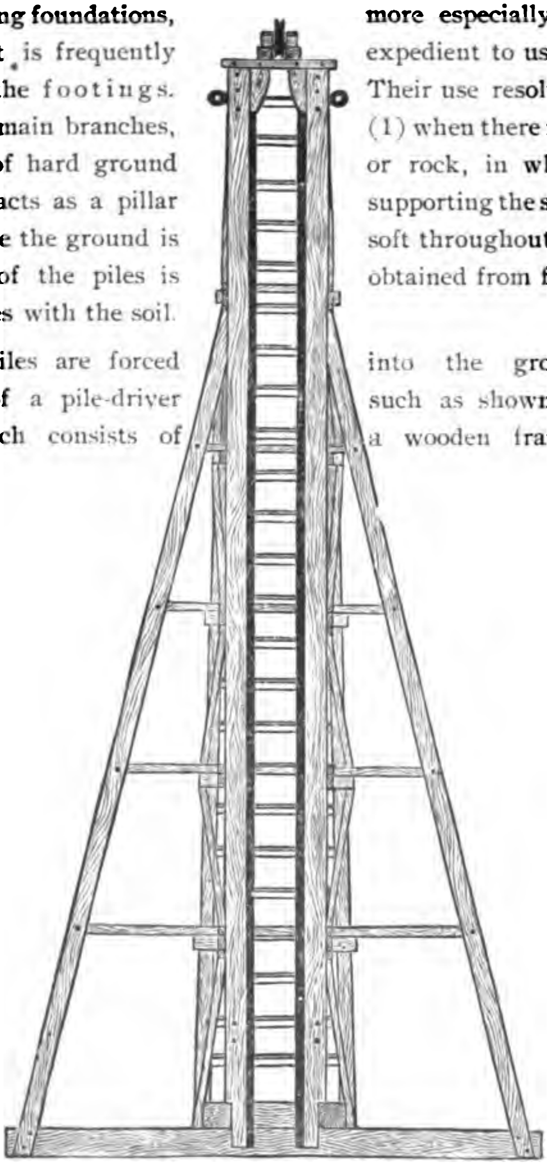


Fig. 57.

porting vertical iron-shod guides, in which slides a heavy mass of iron termed the monkey or ram (Fig. 58). This monkey may weigh from 1000 lbs. to over a ton and is drawn up by means of a steam or hand-winch, the rope being connected to it by a pair of tongs, which are disengaged either by a hand line or by coming into contact with adjustable wedges on the uprights set to regulate the height of fall. After the blow the rope is lowered and the tongs automatically grip the ram once more.

The *gunpowder pile driver* consists of an ordinary pile-driving frame similar to Fig. 57, together with a monkey or ram, this latter having plungers projecting from its top and bottom. There are cylinders fitted at the head of the frame and on top of the pile, which fit these plungers, and into the lower one, on the pile head, is automatically dropped a pellet of gunpowder or other explosive at each stroke of the monkey. The monkey comes down, its plunger entering the cylinder compresses the air to such an extent that it explodes the powder by the heat generated, thus not only driving the pile down but blowing the monkey up preparatory for the next stroke. A pawl on the monkey catches in the teeth of a continuous rack on one upright, and prevents the monkey falling again until a pull on the cord releases it.

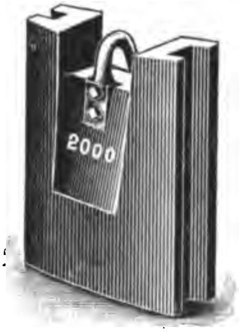


Fig. 58.

Steam Pile Driver.—When a number of piles have to be driven to a considerable depth, it will be advisable to employ a modified form of Nasmyth's steam pile driver. In this machine the steam cylinder, which is one with the ram, is made to rest on the top of the pile; the ram is lifted by steam power and allowed to

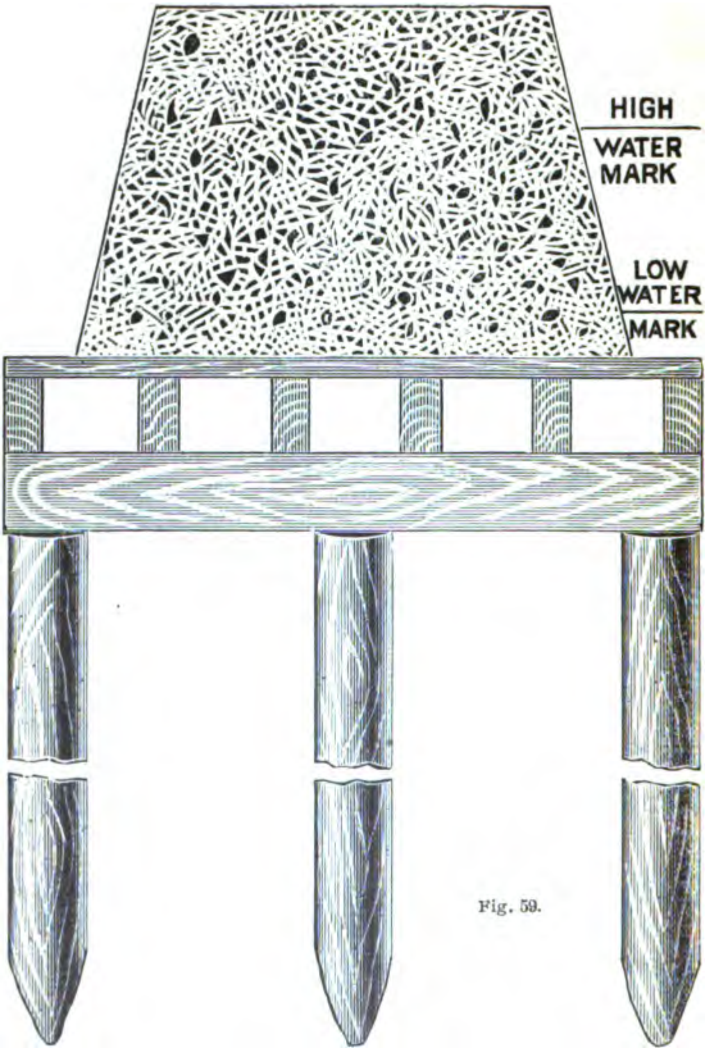


Fig. 59.

fall by its own weight on the bottom casting or bonnet (the foot of the piston rod) which embraces the top of the pile and prevents it splitting. The ram varies in weight from 500 to

5000 lbs. and makes up to seventy blows a minute. The pile driver works between the guides of an ordinary frame, being suspended and paid out at will by a tackle, while steam is led to the cylinder through a flexible hose. The great advantage of this machine is, that there is less risk of damage to the piles and through the great rapidity of the blows there is no time for the disturbed ground to settle, thus enabling work to be done which would be impossible to the ordinary pile driver.

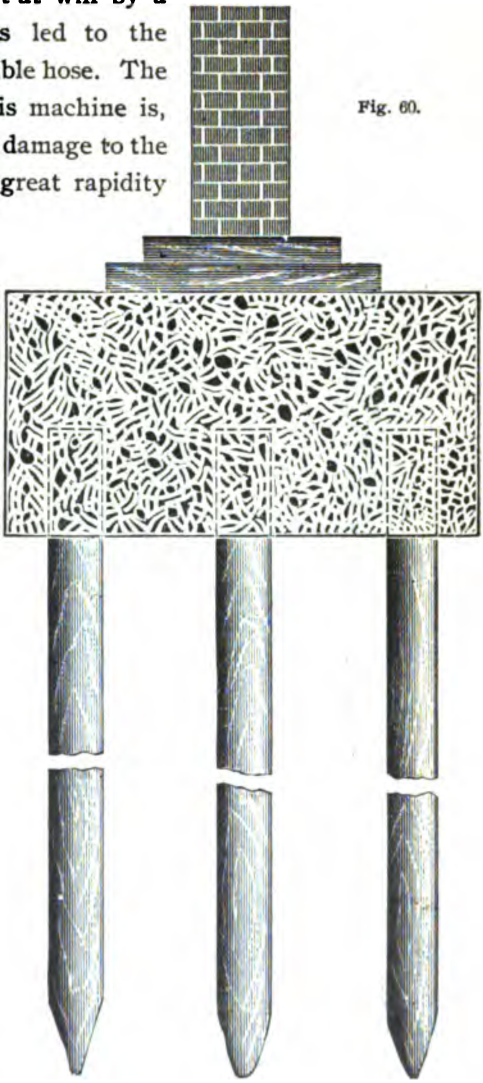


Fig. 60.

Piles should not be less than 6 inches diameter, and are preferably at least 8 inches for heavy buildings, their centres being not less than two or more than three feet apart, unless united with a heavy grillage or frame-work and flooring on their tops. A depth of 30 to 40 feet to the hard ground or rock is all that should be permissible, and a depth of 40 feet in soft ground should suffice. The woods used are oak, yellow pine, spruce or teak. In sea-water, a mollusk, the teredo navalis, is very destructive, boring holes in the piles, hence creosoting or copper sheathing is requisite, or a wood like greenheart, which the teredo avoids, is used. The pile should have a blunt point, and preferably should be shod with iron straps of 2½" x ½" section.

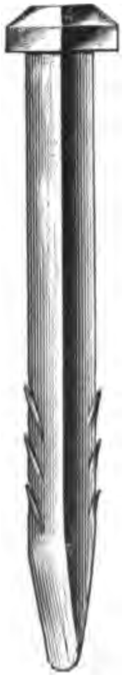


Fig. 61.

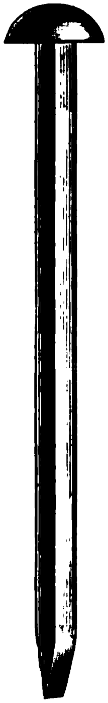


Fig. 62.

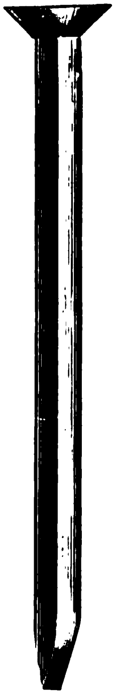


Fig. 63.

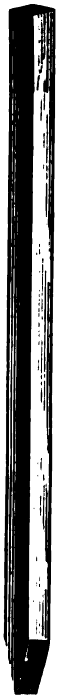


Fig. 64.

In driving piles for foundations the fall is from 5 to 20 feet, it being usual to deliver the last blows rapidly with a short fall. When 8 inch piles have been driven 20 feet into sand or gravel,

PILING AND GRILLAGE.

and refuse to go more than ½ inch with five blows of a 1200 lb. monkey; further blows will only "broom" the head of the pile, or risk splitting and crushing its intermediate portions, while it is amply able to bear the crushing load of the timber.

In a water-impermeated ground, it is distinctly advisable that the piles be completely buried in it, as in that case they are better preserved. This should be observed especially within the range of tidal influence, as in Fig. 59, where the piles, having been driven, are sawn off level, and a "grillage" constructed on their tops, firmly uniting them and bearing the concrete footing which extends from below low-water mark to the desired height.

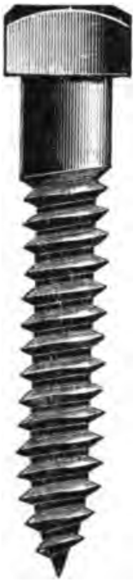


Fig. 65.

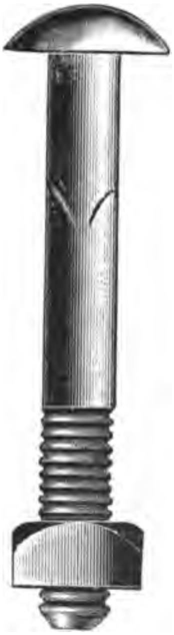


Fig. 66.

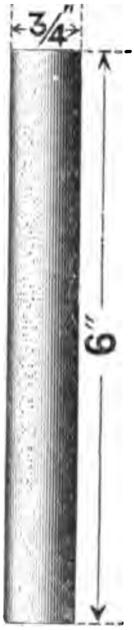


Fig. 67.

FOUNDATIONS.

This framework should consist of 8″ x 6″ beams with 8″ piles. and a flooring of 3″ or 4″ planking should be laid.

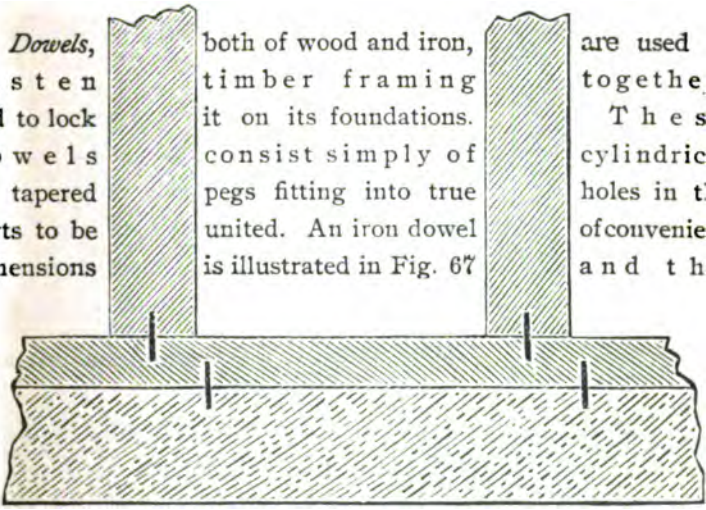
Figure 60 shows a modification in which the piles, after being properly driven, and their heads fairly level, are capped with concrete which embraces the heads and makes a firm level surface, preferably diagonally. When the ground is very soft, this capping becomes a necessity, the upper soil being removed and a bed of concrete at least 3 feet thick being constructed to sustain the weight of the footings as if it were the solid ground itself.

Timber foundations are fastened together in a variety of ways. The chief methods of scarfing or splicing timbers are illustrated and described on pages 37-41, and the student will find much information respecting tenoning and framing of wooden structures in the latter portion of this book, specially devoted to these subjects. It is advisable, however, to recapitulate here the necessity for making *abutting surfaces perpendicular to a compressive force*, and also the need of carefully notching the timbers of grillages into the tops of the piles,as well as into each other.

A variety of spikes are illustrated, Fig. 61 being made barbed or ragged to give better grip; Figs. 62 and 63 have oval and countersunk heads to give a finished appearance to the work; while Fig. 64 is used where a head is unnecessary or undesirable.

A convenient fastening is exemplified in the *lag-screw* or coach-screw, Fig. 65, which has a square or hexagon head for the application of a spanner, thus being turned more readily than with the ordinary turn-screw. It is used to connect iron parts of machinery, etc., to wooden framing or to unite portions of the latter, more especially for parts which may have to be taken apart again. The lag-screw is not believed to have as firm a hold as a driven spike, and certainly takes longer to apply. The *carriage bolt,* Fig. 66, makes a first-class fastening, easily inserted or removed, and useful for either permanent or temporary work. Such bolts may have either a square or round neck, the former of which is undoubtedly the better, and the square nut is usually put on with the chamfered edge inwards.

Dowels, both of wood and iron, are used to fasten timber framing together, and to lock it on its foundations. These dowels consist simply of cylindrical or tapered pegs fitting into true holes in the parts to be united. An iron dowel of convenient dimensions is illustrated in Fig. 67 and the method of using is clearly shown in Fig. 68. above.



Beams can be supported on concrete or masonry footings without the need of cutting the stone, by using a longitudinal sill, as in Fig. 69. This sill is doweled on to the upper surface of the footing, the beam being joggled or keyed into it, as illustrated, and spiked down, making a speedy yet solid job.

FOUNDATIONS.

For piling and heavy framing, woods that are convenient to obtain and abundant, and consequently cheap, and which can be obtained in large dimensions, are generally chosen. Still for wood which is to be buried in the ground, or to be used for spiling durability is almost the first consideration although, in some instances, extra strength is more advantageous. All woods kept dry or submerged last indefinitely—many hundreds of years, although finally they lose their strength and become brittle.

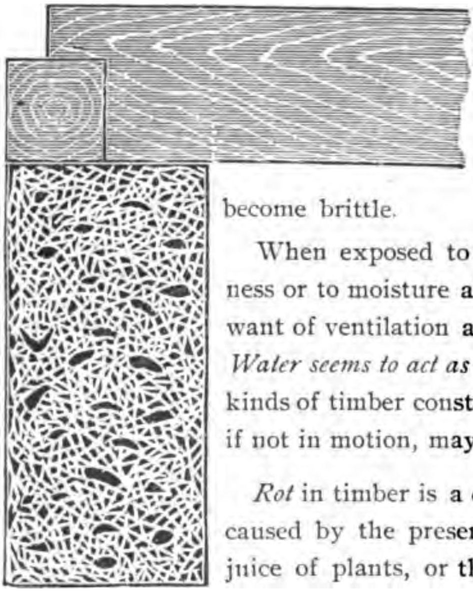


Fig. 69.

When exposed to alternate wet and dryness or to moisture accompanied by heat and want of ventilation all woods rapidly decay. *Water seems to act as a preservative* and some kinds of timber constantly immersed in water if not in motion, may endure for a long time.

Rot in timber is a decomposition primarily caused by the presence of *sap*. This is the juice of plants, or the circulating liquid in which take place the changes necessary for vegetable growth. This decay in woods is spoken of as *dry rot* and *wet rot*. The latter occurs only when the wood is kept damp or is subject to alternate dryness and moisture. Dry rot is generally caused by the want of ventilation.

Confined air, without much moisture, encourages the growth of the fungus which eats into the timber, renders it brittle and so reduces the cohesion of the fibers that they are reduced to powder ; in the first stage of rottenness the timber swells, changes color and is often covered with mouldiness.

STONE FOUNDATIONS.

Stone is denominated rock as long as it remains in its natural position in the ground; when removed and wrought upon rock becomes, commercially speaking, stone.

Tools used in stoneworking, while numerous, are but variations of a few types. Roughly dressing stones of all classes is done by the hammer alone, without the intervention of chisels or similar cutting instruments. The *scabbling hammer*, a modification of Fig. 55, is of varying sizes; indeed, for dressing granite it may weigh as much as 22 lbs. With it the stone is roughly dressed, flakes being knocked off to bring it to shape and size.

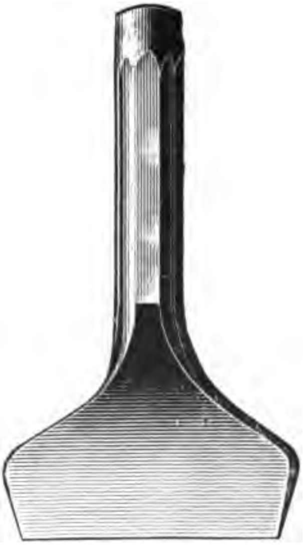


Fig. 70.

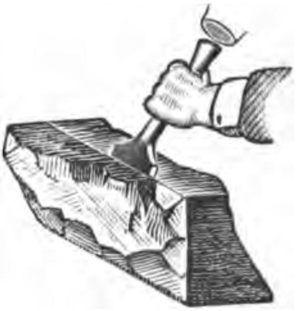


Fig. 71.

A scabbling hammer for dressing freestones is pointed at both ends,

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NOTE. Soft freestone can be cut to shape for facing, etc., with a *cross-cut saw*, but harder stones require the *frame-saw*. This resembles the carpenter's tool, except that the steel has no teeth. The stone is cut by means of the abraded sand combined with water dripping into the kerf from a can. The frame saw is suspended from a rope rove through a pulley on a tripod erected over the block, a counter balance for the saw descending from the other end of the rope.

STONE FOUNDATIONS.

like a boiler scaling hammer, and variations of this type are known as the *pick* and the *axe*, and are used for intermediate finishing, or roughly dressing blocks for concealed work.

The stone mason uses hand hammers of various sizes, and the special *mallet*, Fig. 74, of hardwood, generally hickory. Fig. 70 represents a *pitch chisel for use with a hammer* to square off the ends and faces of the stone block, so as to give level surfaces or *pitches* wherewith to set the stones true by each other. This use of the pitch chisel is shown in Fig. 71.

After pitching it is necessary to bring the stone to a level surface, and therefore it is crandalled. The *Crandall*, Fig. 72, consists of a number of steel blades with chisel points, keyed into a frame; it is used to bring the hewn stone to a true surface; the inequalities of the stone being reduced, and a number of small parallel furrows made, showing on the face of the work.

Modifications of the Crandall are the *bush hammer* and *patent axe*, in which the same idea of a number of removable cutters with wedge or pyramidal points is utilized.

The nature of surface left after the operation of crandalling is well shown in Fig. 73, the *bush hammer* giving a finer surface. A variety of chisels, ranging from ¼" to 4" wide on the edge, are used, also chisels with tooth edges, known as *combs*. When intended for use with the mallet, all stoneworker's tools have a peculiar, round cup-shaped head.

Blocks of stone or concrete require careful lif ing by a crane, so that they may be lowered accurately into the bed of mortar prepared for them, thus avoiding pushing or levering the stone into place, which may result in displacing the neighboring unset portion of the wall. The attachment to the crane is usually by:—(1) The Lewis, as in Fig. 77, where the dovetailed portions A & C are first put into a similar dovetailed recess cut in the stone immediately above its centre of gravity. The centre or locking-piece B is next inserted, the shackle brought to its place, and the whole pinned together. (2) *Round Lewises* or curved plugs as shown in Fig. 76, in which the strain of the lifting chain tends to pull the two bent wedges closer together at the top, causing them to grip the stone tightly. (3) Iron claw

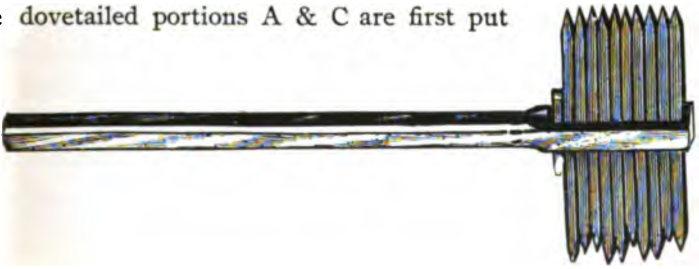


Fig 72.

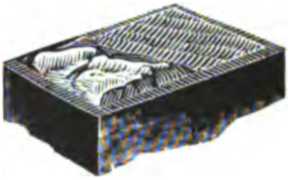


Fig. 73.

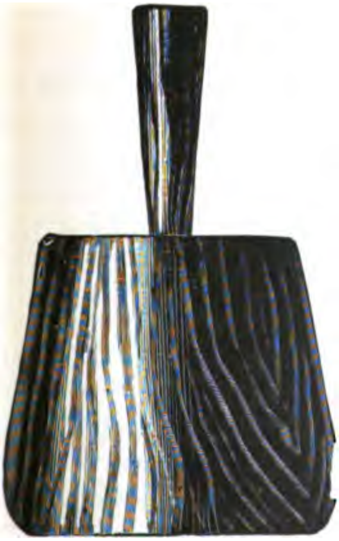


Fig. 74.

hooks similar to Fig. 75, which fit into holes prepared in the sides of the block, in the same vertical plane as its centre of gravity.

Fig. 79 shows the usual method of slinging a heavy stone or similar long articles by means of a strop or endless rope. Fig. 78 represents that most useful rope fastening, the *timber-hitch*, which may be largely applied in dealing with the bulky beams and blocks mentioned in the preceding section. It has the advantage of never slipping, and of holding the tighter, the greater the strain applied.

There are three usual types of masonry in use, known as rubble, block-in-course, and ashlar.

Rubble masonry is used where the stone is rough, hard to work, or lies in thin beds only. Its simplest form is *rough or common rubble*, wherein the stones are laid at random, just as they come to hand, the only tools used being a trowel, hammer, and plummet: care is taken to lay bonding stones through the wall for, at least, each superficial yard. Where the stone is distinctly "bedded," or stratified, and workable, but varies in size, the blocks are all roughly squared and hammer-faced beforehand, ready for building into the wall; this forms *random coursed* or *squared rubble*, which makes, when a good proportion of large and bonding stones is used, a strong and effective wall for engineering purposes. In more expensive rubble work, the stone is not only squared and faced but is carefully laid into courses with one-fourth of each course consisting of headers or bonding stones. This *coursed* rubble has $\frac{4}{10}$ the strength of the stone itself.

TOOLS FOR STONE WORK

Block-in-course masonry is used where a suitable stone is obtainable, and good work is desired, as in piers, foundations, revetments and the like. The stones are all squared, essentially being less than 12 inches deep, with a length of about four times their depth. Each course consists of single stones only of uniform thickness, no attention being paid to variation of depth between one course and another. These courses may vary all the way from 4 to 10 inches.

Ashlar masonry is where the stones as a rule exceed 12 inches in depth, and are carefully scabbled or sawn into shape; usually being fitted into place, and laid in as uniform a course as possible, with a depth of 10 to 14 inches. This is the style usually adopted in public buildings, where the best work is demanded.

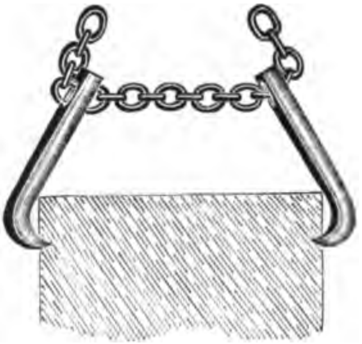


Fig. 75.

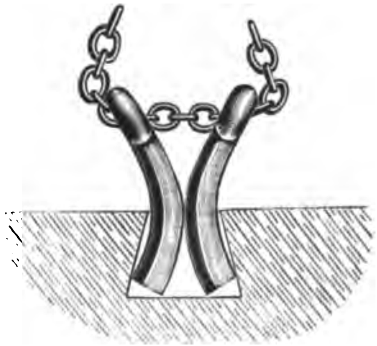


Fig. 76.

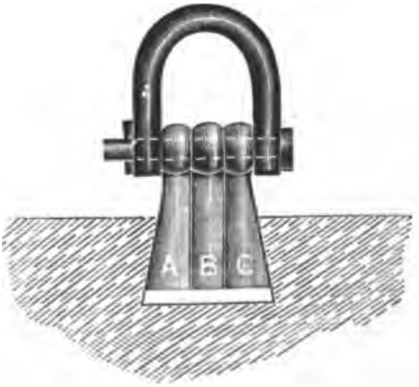


Fig. 77.

STONE FOUNDATIONS.

It is necessary to proportion the length and breadth of stone blocks to their depth, for fear of their breaking across. The safe proportions vary from 3x2x1, with the softer freestones, up to 4½ and 5x3x1 with hard stones that can bear a crushing load of 350 tons per square foot, It is also advisable to lay the blocks alternately lengthwise and across (stretchers and headers), or, that at least one-fourth of the face of the work consist of headers, with the stones breaking joint by no less than the depth of the course.

The joints may vary in thickness from one-eighth to one-half inch, depending upon the amount of labor expended in giving smoothness to the bedding-faces, as in any case there must be sufficient thickness of mortar to transmit the pressure from one block to another, without permitting any stone actually to touch its neighbors. Large stones should be fitted, and then laid on a bed of mortar prepared for them. It is a good plan to first cement up the outsides of the vertical joints and then, pouring in cement or mortar grout, work it into the openings with a piece of hoop-iron.

Figure 81 shows the method of laying common *rubble masonry*, as for foundation walls; it will be noticed that each stone is carefully set in a bed of mortar, and that the horizontal joints are properly broken, that is, the joint between two stones on one course comes over the middle of another in the next course; a proper proportion of bonding stones, or transverse blocks laid right through the wall, is provided, to give stability and "lock" the whole together.

Figure 80 shows careless work, to avoid which supervision of the masons is necessary on the part of the builders. The joints of three or four courses are above one another, together with numerous voids, or spaces without stone, making the wall unduly weak, and liable to settle and slide immediately any weight is placed upon it. The only remedy is to pull the whole wall down, and rebuild it properly with bonds, and with all interstices properly filled as indicated above. The importance of this advice justifies the use of the illustration, which, however, must not be considered a sample of even "fair" workmanship.

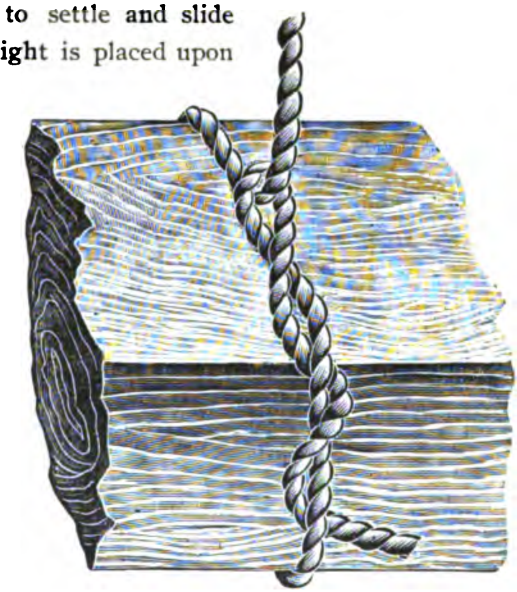


Fig. 78.

Care should also be taken to leave proper openings for any pipes that may have to come through the wall, and to frame such openings with large stones, so that settlement shall not occur.

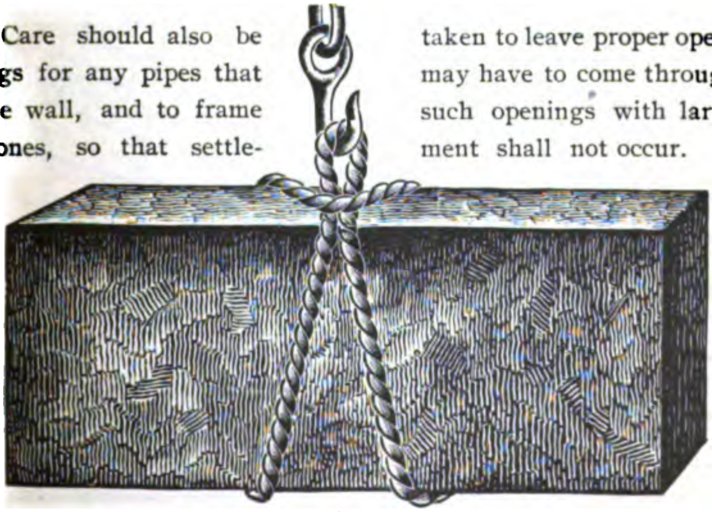


Fig. 79.

STONE FOUNDATIONS.

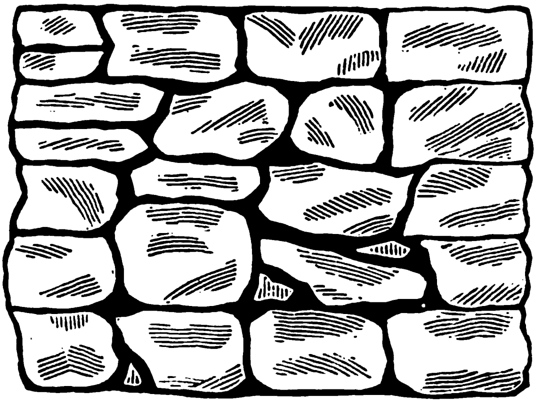


Fig. 80.

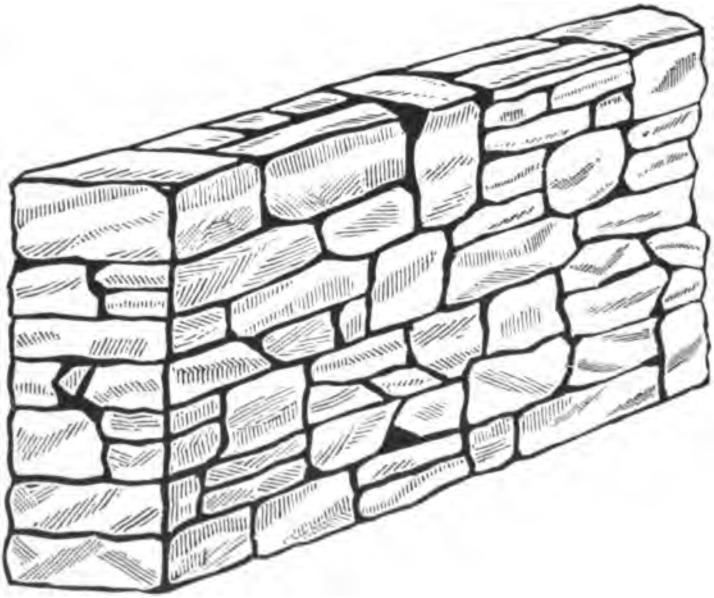


Fig. 81.

MORTAR AND CEMENT.

Mortar is a cementing material used to bind together bricks or stones into structures, consisting of a mixture of lime and sand with water. It "sets" or hardens in the air, and not under water, its setting consisting in the changing of the hydrate of lime into the carbonate by the absorption of carbonic acid from the atmosphere. This naturally is a slow process. Hardening also depends upon the crystallization of the mortar, and is greatly faciliated by using uniform sand of sharp and angular nature, as lake or river sand.

Good mortar, if free from dampness, hardens from year to year, and becomes as strong as the material it unites.

Natural Cement is a binding material, made by calcining impure limestones containing sand and clay. The rock naturally consists of carbonates of lime and magnesia, with silicate of alumina.

Portland Cement consists of chalk and clay ground together, dried and then calcined to a dark hard mass or clinker, which is subsequently crushed and ground to a fine powder of a slaty blue color. It has the valuable property of hardening in water, and bears a tensile strain of 350 to 550 lbs. per square inch, depending upon the length of its immersion.

NOTE.—In preparing cement the stone is burnt in kilns with a mixture of coal dust, and consequently ground to the requisite fineness in mills. Natural cements are lighter than Portland cement, set much quicker, but have less strength, though sufficient for ordinary building operations. The *Rosendale Cement* made from cement-rock found in Ulster County, New York, and *Roman Cement* obtained from nodules found in the London Clay are the most celebrated.

MORTAR AND CEMENT.

The induration or setting of Portland cement consists in the formation of a real mineral of the crystalline-rock species, analogous to natural zeolites. The slow setting of the cement should be obtained by care in the burning and elimination of all incompletely burnt clinker, and not upon the admixture of gypsum, which is an element of danger. See note below.

Grout is mortar or cement admixed with sufficient water to render it fluid, for the purpose of pouring into and filling interstices in masonry that are otherwise inaccessible.

Plaster is a mixture of lime and sand with water, hair being added to serve as a binding material. It is carefully mixed up into a paste, and used to coat the interior walls and ceilings of houses, being spread for the purpose on a prepared framework of wooden laths.

Plaster of Paris consists of calcined and ground gypsum, a natural sulphate of lime, found in immense beds in the environs of the French capital from which it derives its name. It sets rapidly when made into a thin paste with water, possessing the valuable property of expanding as it sets, consequently is much used for making moulds, luting joints, and filling cavities where other materials would shrink ; also for cornices and ornaments.

For tests, it is wise to see that the cement conforms to the following requirements: 1. It should be ground so fine that not more than 15 per cent. fails to pass through a sieve with 76 meshes to the lineal inch, the wires being of a size equal to one-third the distance of their centres. 2. A pat mixed with the minimum of water, and left on a glass or china slab, should not commence to set in less than eight minutes or take longer than five hours to set hard. 3. Briquettes of neat cement after gauging with the minimum of water on a non-porous bed, placed in water after twenty-four hours should carry an average tensile strain of 400 lbs. per square inch after hardening in the water six days, and should not exhibit any cracks or blotches after being under water 24 hours.

BRICK WORK.

Brick is an artificial stone, made by forming plastic clay into a rectangular shape, and then burning it to expel all moisture and thoroughly harden it. The sizes of bricks as usually made are 8¾″ x 4¼″ x 2¾,″ which when laid in cement, makes each brick occupy a space measuring 9″ x 4½″ x 3″; thus the width and height are one-half and one-third of the length respectively, admitting even building in courses with the bricks laid in different directions.

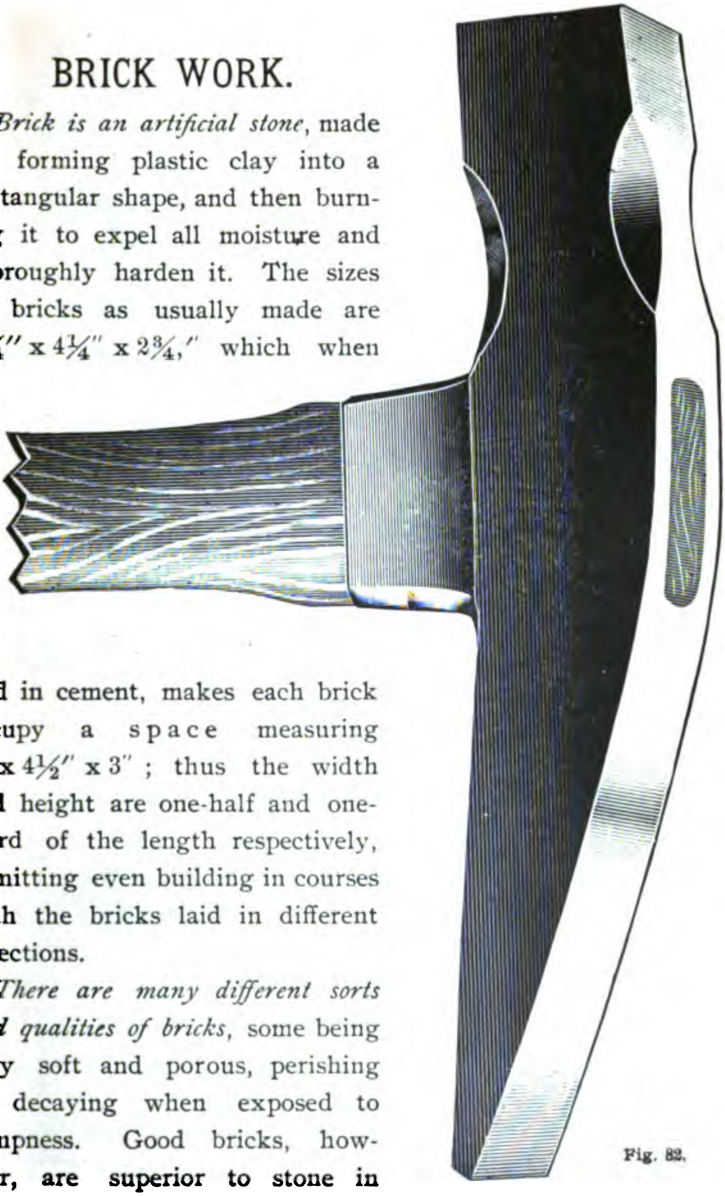


Fig. 82.

There are many different sorts and qualities of bricks, some being very soft and porous, perishing or decaying when exposed to dampness. Good bricks, however, are superior to stone in

BRICKLAYERS' TOOLS.

resisting the action of the weather, the acid gases diffused through the atmosphere, or even fire, and are practically indestructible from those causes. They are obtainable in every convenient form, and of a variety of colors, the latter varying as the percentage of iron in the clay. The color is white with

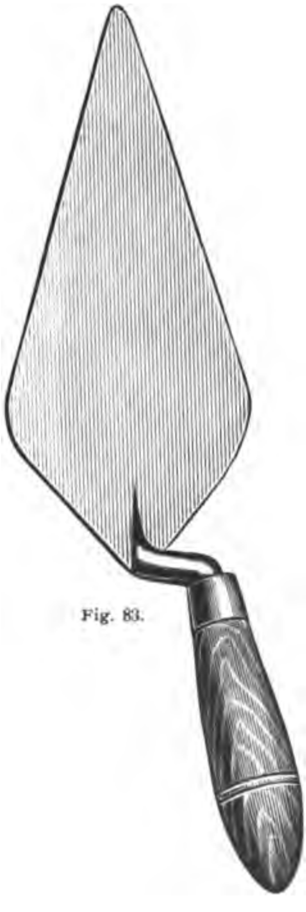


Fig. 83.

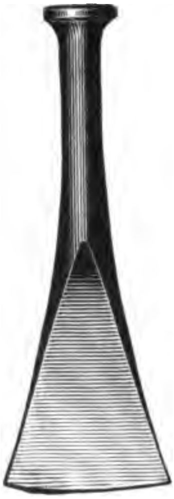


Fig. 84.

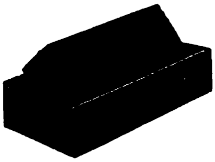


Fig. 85.

only one per cent. of iron, passing through buff and orange to deep red with six per cent. of ferric oxide. Bricks containing a high percentage of oxide of iron, if fired hard, will pass from red to blue and almost to black, forming the celebrated blue bricks so much in use for engineering works.

Good brickwork is much cheaper than ashlar stone, and is generally less expensive even than rubble masonry; the walls are usually one-fourth thinner than with stone; a crushing load of 250 tons per square foot can be sustained; and the weight of a cubic foot of laid brickwork and mortar may be taken at 112 lbs. A cubic yard of brickwork will contain 400 bricks.

The bricklayers' tools are not so numerous as those of the stone mason. For cutting bricks exactly to size he uses a tin *saw*, and *chisels*, as shown in Fig. 84. The brick is first nicked around with the tin saw and the superfluous end knocked off with the *hammer* represented in Fig. 82; the brick being next laid on the *chopping block*, see Fig. 85, and brought to a smooth edge with either the chisel or a *bricklayers' axe*, the latter having a long blade about one inch wide set in a suitable holder, so that the tool is used like an adze.

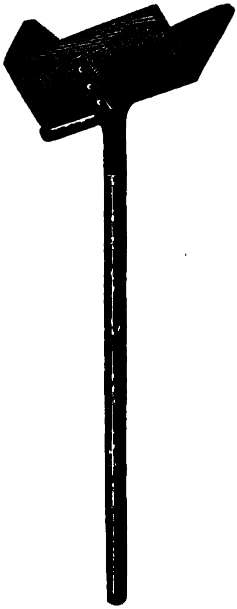


Fig. 86.

Soft bricks are cut to the desired shape with a *frame saw*, in which the cutting edge consists of two twisted steel wires, and are then *rubbed* smooth on a slab of gritty stone. It is better, however, and cheaper to buy shaped stock bricks for arches or irregular work than to cut plain ones.

Bricklayers as well as stone masons use the *plumb level*, Fig. 39, the *spirit level*, Fig. 36, and the *square*, Fig. 38.

The mortar is spread on the beds by means of the *trowel*, Fig. 83, the mason picking it up as required off *mortar-boards*, which are some 30 inches square, onto which the mortar is tipped from the hod, Fig. 86, which is used for transporting mortar as well as bricks to the various parts of the scaffolding.

Bricks absorb one-fifth their weight of water, and should be laid wet, with a thin even bed of mortar filling all irregularities, but of such thickness that eight courses of laid brickwork stand two inches higher than the same number of rows of stacked bricks. The object of wetting the bricks is to prevent them absorbing moisture from the mortar, and thus spoiling the latter's setting. In frosty weather the bricks should be laid dry, with warm mortar made from freshly slaked lime, care being taken that there is no frost in the bricks.

Bonding is the art whereby a mason binds his work together. The two great principles to be observed are, (1) that a proper proportion of transverse bricks or blocks of stone are put into the wall to tie the back and front of the wall together; (2) that a joint between two bricks or stones in any course should be opposite the solid part of the courses above and below. The process of making the joints in one row out of line with those in the others is termed "breaking bond."

BRICK WORK.

English bond, Fig. 87, is one of the most usual styles of bonding brickwork, and is the strongest and simplest for ordinary work. The courses of stretchers or longitudinal bricks, as at C, alternate with courses of headers or transverse bricks as

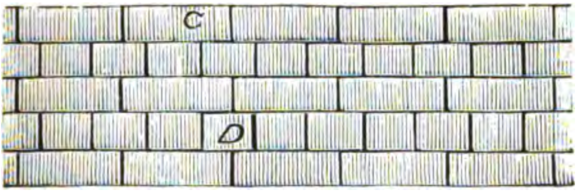


Fig. 87.

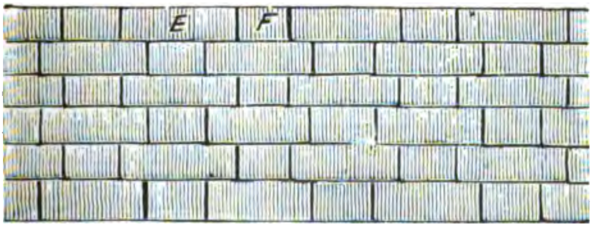


Fig. 88.

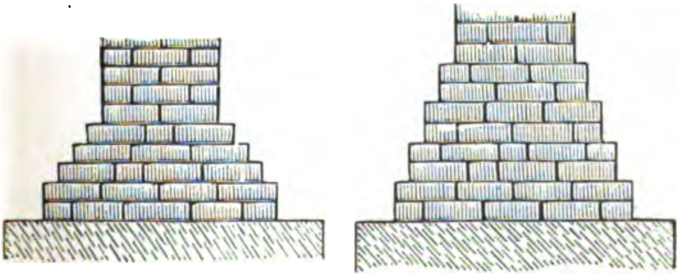


Fig. 89.

shown at D on the figure. This makes the strongest joint known, care being taken that each header joint comes on the centre of a stretcher. It is not necessary to alternate the courses, unless the strongest possible wall is demanded. Hence for nine-inch walls which are required to show a fair face on each side we may use the *garden wall bond*, in which three or four courses of stretchers are used to one of headers, it being clearly necessary to see that all header-bricks are of uniform length.

The *Stretcher-bond*, shown in Fig. 90, is used for half-brick walls, as partitions, etc., bats or half-bricks being used for the few header courses at A and B. The same bond is used for nine or fourteen inch walls in cheap work, but if a substantial job is required there should not be more than three courses of stretchers for one of headers. The bonding must be carefully watched.

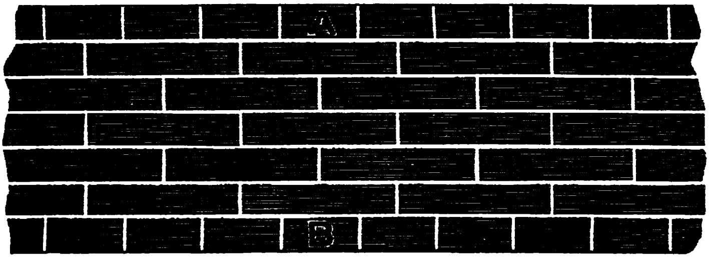


Fig. 90.

The *Flemish bond*, Fig. 88, is almost exclusively used for walls up to 1½ bricks thick, as it presents a uniform surface on each side, and has a more pleasing appearance than English bond. It is not so strong however, but gives a smoother face on each side for nine-inch walls. In this bond, stretchers as at E, alternate with the headers F, in the same course.

BRICK WORK.

It is advisable to insert hoop-iron bonds as shown in Fig. 91 to strengthen walls longitudinally. They are very useful for such purposes also as temporarily holding together work erected on bad foundations. They should be from one inch to one and a half inches wide, and from No. 18 wire gauge to No. 16 in thickness. It is necessary to test them well, and bed them in cement, as, if they are allowed to rust, they swell and injure the wall.

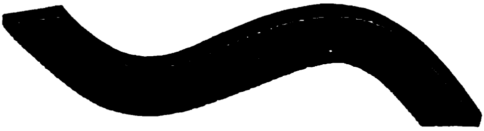


Fig. 91.

Footings of brickwork are formed of successive courses of bricks, and, no matter which style of bond is used, either English, modified or Flemish, the footing courses are always laid in *Header bond*, that is, each course consists of transverse bricks only. This ensures each brick overlapping three-fourths of the one beneath it with consequent distribution of weight, when, as is customary, each brick projects one-quarter brick or 2¼ inches beyond the one above it.

This is well illustrated in the left hand view of Fig. 89, which represents an efficient method of laying foundations for sustaining heavy loads. As each course is half-a-brick wider than the one above it, it will be necessary to lay a single row of stretchers in each alternate course, but these will be placed as near the centre as possible, and will not show on the face.

BRICK WORK.

The right hand footing in Fig. 89 shows a useful practice of building the footing courses double, and this should be adopted in all cases where it is permissible to omit the usual concrete bed. This possesses marked advantages where the loads are very heavy, but of course it doubles the height of the footings, and increases the cost. This double course method of constructing footings will give a face of English bond, header and stretcher courses alternating.

The mortar by which the bricks are united together, is made with one part of lime to 2½ or 3 parts of sharp, that is angular fresh water sand. The sand is to prevent the mortar being crushed out, as it is setting, by the weight of the masonry. *A quick setting cement* is made by using equal parts of natural or Rosendale cement and Portland cement, while a good, economical, and strong binding material is obtained by using one part of natural cement with four of lime mortar.

The lime mortar should be well worked, and the lime thoroughly slaked before the cement is added; only sufficient for the immediate needs being mixed at one time. If good work is desired, especially around engine foundations, or in the building of structures liable to the vibration of machinery, it is requisite to use Portland cement.

Portland cement mortar consists of equal parts of sand and cement, and is greatly to be recommended for foundations or damp places generally. In each case the materials require to be wetted with one-third their bulk of water. Each cubic yard of brickwork requires about 9 cubic feet of mortar.

ANCHOR BOLTS.

An anchor is any device for holding an object to the ground or to other fixed objects or for resisting tension or the like, as the anchor of bridge cables. Again, it may be a clamp, often ornamental on either end of a tie rod; used to prevent the bulging of a wall or the spreading of any related constructive member. Hence an *anchor bolt* as here used means a rod to fasten or anchor a superstructure to a foundation.

Anchor bolts for fixing machines to their foundations are of various types, some of the more usual being illustrated in the accompanying figures.

Fig. 92 shows the bolt held in place by a cotter which retains the anchor plate against the lower side of the concrete bed. This construction generally calls for manholes or armholes in the foundation to give access to the lower end of the bolts.

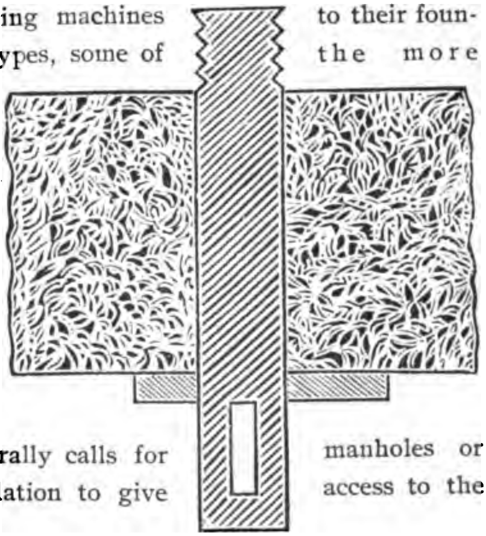


Fig. 92.

Fig. 93 gives an ordinary method of fixing machines, where the bolts and anchor plates are suspended in their proper position from the foundation template, and concrete filled in on top of them, care being taken to provide some method of holding the bolt so that it shall not turn around in screwing up.

ANCHOR BOLTS.

Figs. 94 and 95 show superior methods to that just described; a piece of iron pipe in bore about twice the diameter of the bolt, or not less than 2″, is cut off to a convenient length and suspended on the bolt and anchor plate from the foundation template. It is well to be sure that the pipe is cut off square at each end, and that its top is well below the upper surface of the bed.

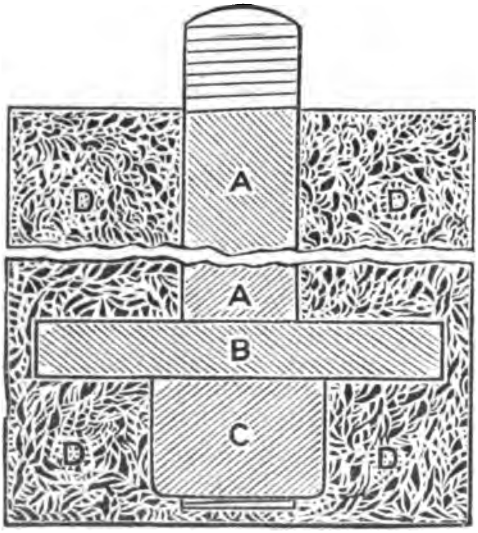


Fig. 93.

The anchor plate illustrated in Fig. 96, and in sectional elevation in Fig. 97, is to be recommended, as it prevents the nut from turning around, as the bolt is tightened, and also acts as a guard to prevent the nut falling off into the pit, by any mischance. Fig. 94 illustrates this plate in position, while Fig. 95 shows the same type of plate without the nut-locking device.

In putting in bolts in pipes, slight shifting of the bolts, to accommodate the holes in the sole-plate, can easily be accomplished without side strain, and this method is always advisable, as holding-down bolt-holes in bed plates are often only cored out and consequently irregular, while settling of the machine bed may easily take place.

In working with a template, it is well to fix it at such a height that its top face occupies the level proposed for the upper face of the sole-plate. The length of bolts can then be easily gauged, and much cropping avoided, more room is obtained to work under the template, and the necessary height can be easily checked with the rule.

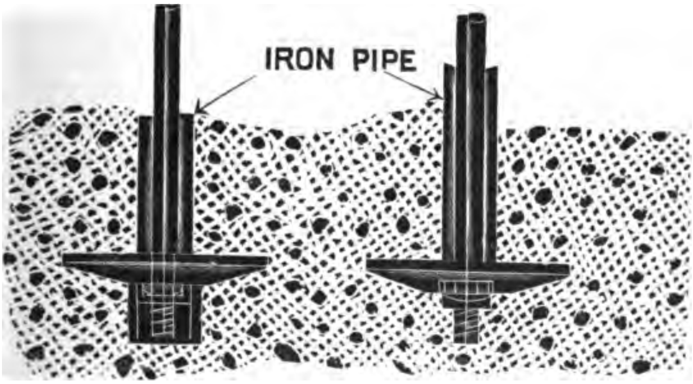


Fig. 94. Fig 95.

A rag bolt, as Fig. 98, is used to fix bolts into stone blocks, the bolt being jagged with a chisel, and forged slightly tapering practicable; the space between the bolt and the sides of the conical hole in which it is set being filled by pouring melted lead into it, thus gripping the bolt fast.

The *lewis* bolt, a better device for attaining the same end, is made in the form of a pyramid or wedge, with stepped sides; sometimes the tapered and stepped portion is part of the bolt, at others it is a separate casting or forging. In some cases the bolt screws like a stud into the lewis; otherwise the

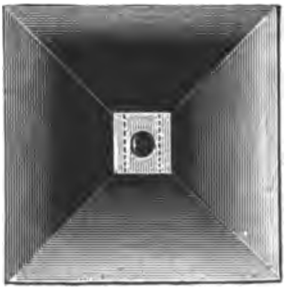


Fig. 98.

Fig. 97.

taper is threaded on the bolt, whose head fits snugly into a properly-shaped recess in the base of the lewis. As with the rag bolt, the lewis is fitted into a dovetailed hole, and is held firmly in place by filling up the surrounding space with melted lead.

Screw guy anchors make an excellent attachment for temporary purposes, such as mooring derrick guys, or providing anchorages for tackle, as in erecting or wrecking operations. A worm or helix, similar to that used in screw piles, is cast on a square steel bar, barbed so as to retain the cast iron. The worm can be *screwed into clay loam*, *sand or any other soil* and an eye at its upper end affords convenient attachment for the rope. See illustration on page 241.

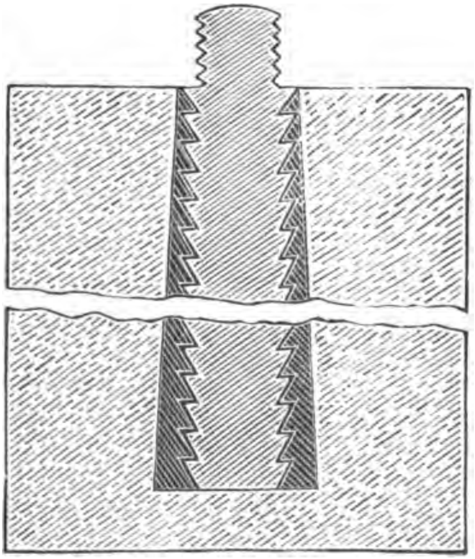


Fig. 98.

CONCRETE.

The word concrete in its original meaning implied a process of "growing together, as of separate parts," hence, a compound of gravel or broken stone, united by means of hydraulic cement, mixed with water *grows* into concrete. This process is termed *setting*, thus concrete may properly be called artificial stone. In recent years *concrete foundations* have been used more in construction than any other method. Its durability and cheapness can well account for this.

Although generally considered to be a discovery of the last century, concrete dates back to the Roman period, and its growth seems to have followed and is proportional to the growth of the Portland cement industry. One of the interesting, not to say amazing, features of modern engineering construction is the varied and extensive uses to which concrete is being put. It may be said that concrete can be used wherever stone is employed, the exception being that the latter may stand a pressure ten times greater, but this remark as to strength does not apply to reinforced concrete, to be described and illustrated hereafter.

There are three kinds of concrete—cement, lime and asphalt or coal tar. The use of any of these depends upon the location, kind of structure, and the required strength, also of climatic conditions. The classification is according to the nature of the binding material used.

Cement concrete is composed of a mass of stone chippings, or gravel, and sand bound solidly together by cement. Portland cement is the usual binding material in concretes. In the proportions of one part cement to three of coarse sand and five of broken stone or large gravel, it will make an artificial rock capable of bearing safely a load of ten tons per superficial foot.

TOOLS FOR MIXING CONCRETE.

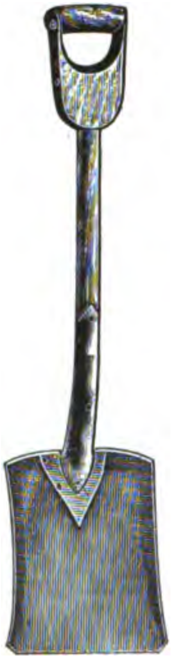


Fig. 99.

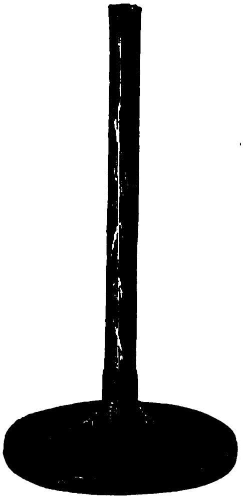


Fig. 100.

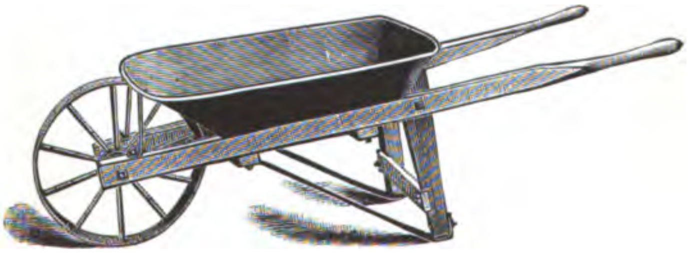


Fig. 101.

CONCRETE.

Broken bricks, burnt clay ballast, ironworks slag or cinder may also be used instead of stone, and the lighter materials may be used to advantage where it is necessary to keep the weight down, as in a concrete floor on a bridge; it should however be remembered that a greater proportion of sand and cement should be used with such lighter and more porous material.

Lime concrete is made by mixing unslacked, or hot fresh ground lime together with four times its weight of gravel and twice its weight of sharp sand, upon a stone, brick or wooden floor. The mixture is raked and spread twice over to dry, and when shoveled into a heap for the third time it should be wetted with water sprinkled from a hose; just sufficient water should be added to slake the lime and cause the compound to adhere in a pasty mass, about one U. S. gallon per cubic foot generally being enough. The mass should be well raked and turned over with hoes and spades while the water is being added.

Ground lime is better for use in the mixture but should a hydraulic lime be used in its lump form, it is preferable to leave it to slake for two or three days well covered up by sand to retain the heat.

NOTE. A practical method of determining the mixture of sand and cement is as follows: A measure, say a large pail or bushel is filled with a representative sample of the material available, whether *gravel, shingle or broken stone.* Enough water is measured into this sample to fill the pail, this represents the quantity of *sand* necessary. The equal quantity of dry sand is placed in another pail and water added to it until it is quite wet, the water equals the *minimum* amount of *cement* required. The theory is that in good concrete there must be enough cement to fill the voids in the larger material and enough cement to fill the voids in the sand.

CONCRETE.

Asphalt concrete is made with Trinidad asphaltum. It is recommended to melt 4 parts of mineral pitch, (from petroleum), in a cauldron, adding first 27 parts by weight of asphaltum broken small, next 1 part of resin oil, and stirring in 2 parts of sharp sand. When the whole is thoroughly incorporated and fluid, it is termed *asphalt mortar* and may be used as such. To form into concrete, it is mixed while melted with nine-elevenths of its weight in broken stone.

Coal tar asphalt is the term frequently applied in the United States to a mixture of slaked lime and gravel, to which is added the waste tar from gas works, commonly known as coal tar. Coal tar, chalk and gravel are also boiled together to give the requisite consistency; this is used as a substitute for the genuine article.

The derivative from petroleum is often termed *mineral pitch*, and serves as a water-proof paint, an anti-corrosive coating, and numerous other uses. The Trinidad asphalts are mixed while hot with sand or fine gravel for the purpose of lining tanks, forming paving, damp courses, roofing, etc.; or they may be used to impregnate paper or textile fabrics for similar purposes.

The French and Swiss rock, so largely used in London and Paris, requires no admixture, crumbling to powder under heat, in which condition it is spread and rolled, regaining the appearance of the original rock on cooling.

NOTE. Asphalt is a name applied to three diverse, allied substances: (1) The base or ultimate result of changes in those petroleums or natural hydro-carbons which do not contain paraffin; (2) Natural deposits of asphaltum or bitumen found in the form of self renewing lakes in Trinidad, (W. I.), Venezuela, and elsewhere; (3) Limestone rock impregnated with 8 to 20 per cent. of bitumen, as found in the Val de Travers in Switzerland.

TESTING CEMENT FOR CONCRETE.

In testing the cement preparatory to mixing concrete, it is customary to form the material into a *pat*. Enough neat cement is mixed, with just sufficient water at 60° Fahr. to make a dough, to form a pat two or three inches in diameter, half an inch thick in the middle, tapering off to one-eighth inch at the edge. The mixing, etc., must be done on a non-porous object, such as a glass slab or a glazed earthenware plate.

The pat must be watched for the first setting, frequently specified as not less than eight to ten minutes, (if possible, longer still), and must take five or six hours to set hard.

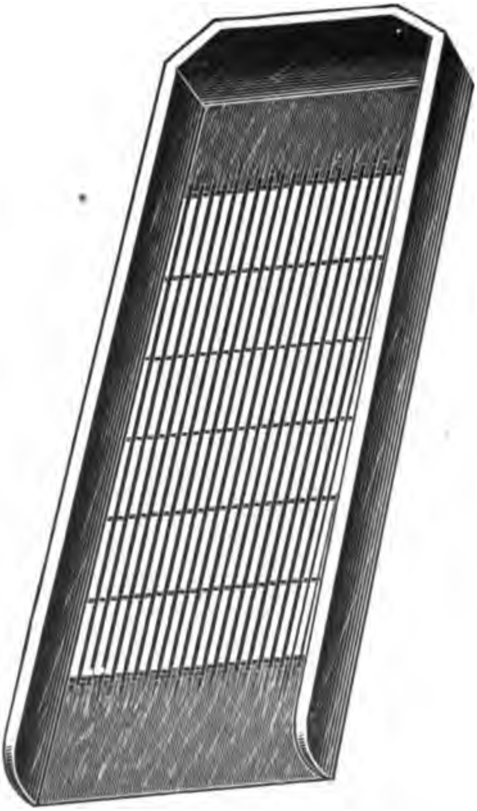


Fig. 102.

This first setting is said to be accomplished when the pat is not indented by the pressure of a $\frac{1}{16}$ inch wire loaded to weigh $\frac{1}{4}$ lb.; on setting hard it should stand a weight of 4 lbs. applied by the same size wire. The pat is then covered with a damp cloth up to the expiration of 24 hours from the time of mixing, and then placed under water, plate and all, to harden. This may be for days or weeks, and the pat should be examined to see that it shows no sign of disintegration along the thin edges, or any distortion and expansion cracks.

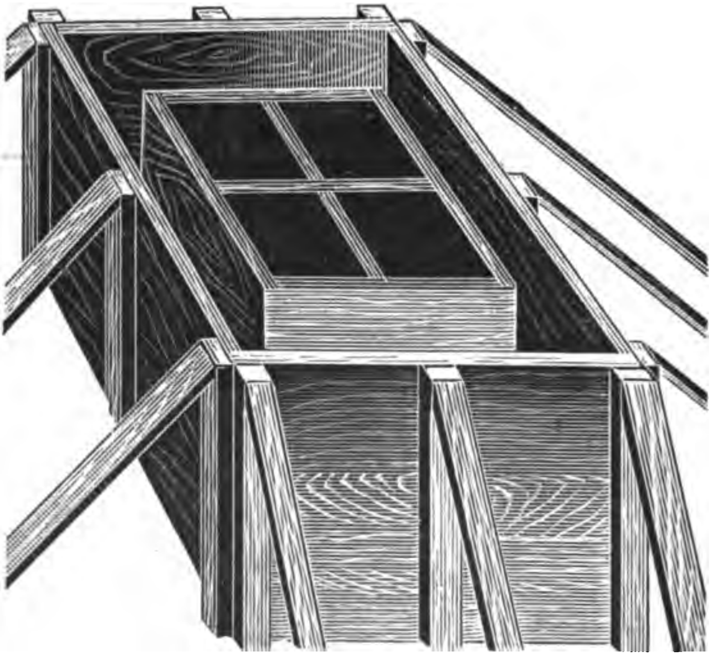


Fig. 108.

Note. In most constructions the proportions of mixing are specified, but as a general rule. which has given very satisfactory results, the following mixture is used : 1 cement, 2 sand, and 5 stone. A piece of work done with the above mixture had to be taken down a few months later so as to enlarge the building, and the concrete broke with the line of fracture through the stone, showing that adhesion of the cement to the stone was greater than the strength of the stone.

PROPORTIONS OF CONCRETE

For the making of a product that is capable of defying fire, water, acids and the forces of nature, for untold ages, *the implements and materials used are most simple and inexpensive.*

Item one, in the outfit, is the so called *mixing board;* the dimensions and practical use of this is indicated by an expert in his own language quoted in the note below.

The 1-2-5 mentioned in the above is the colloquial way of expressing the proportions of the ingredients of concrete, i. e., one of cement, two of sand and five of gravel or broken stone or other mixtures—the cement always leading. In this connection are illustrated the square nosed shovel, Fig. 99, and wheelbarrow, Fig. 101, as they are much used in handling the materials for concrete.

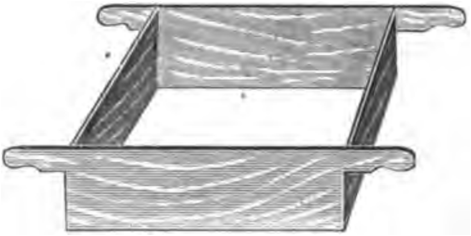


Fig. 104.

It should be remembered by the student that *the proportions* named in these pages are only approximate, as in practical application builders change amount of each material to suit the conditions.

"If mixing a whole batch of 1-2-5, make a board or platform, very smooth on top, size 12x18 feet. Upon this platform or board, first spread the sand and upon this the cement, which should be thoroughly mixed together with square shovels. The broken stone or gravel (which has been previously well wetted) should be spread over this mixture and the whole mixed together. The best way to mix by hand is to turn the material (mixed) over at least twice. During this process, water should be freely sprinkled over it. Regarding the amount of water, authorities differ, but experience has proved that a very wet concrete produces the best results."

CONCRETE.

When concrete is used *as a foundation* or for the walls of a building, the construction is frequently "monolithic," which means, that the concrete *is built up as a single stone*, without joint or seam. Fig. 105 exhibits the usual method of effecting this. A mould is erected with sides corresponding to the inner and outer faces of the desired structure. The intervening space is filled with the semi-fluid mass of the mixed concrete which is carefully rammed down to fill completely the mould.

A good type of rammer for compacting concrete is given in Fig. 100, the face or head being of cast-iron and of ample dimensions.

The use of the shovel has been alluded to; the common use of the indispensable barrow is evident, to which may be added its convenience as a measure, thus:—

> "A good way to measure materials is to use an iron-bodied wheelbarrow, which will hold one-half-barrel cement, or two sacks of cement; most cement used now is packed in sacks, and four sacks equal one barrel."

The screen, Fig. 102, is used for sifting sand from hard lumps or small stones, in the making of mortar. It is also used to separate different sizes of stones for concrete.

The various materials composing concrete are easily proportioned by means of the *measuring-frame* illustrated in Fig. 104; this is placed on *the flat surface of the mixing-floor*, and filled as often as requisite with the proper ingredients by means of a shovel. When filled it is easily *lifted off* by means of the handles at each corner, and no further tipping or moving is required.

Machine foundations are made of concrete by the use of a *form* or mould such as is shown in Fig. 103. The form is made of one or two-inch boards with battens on the outside of the frame, the thickness depending upon its height and size. To obtain a very smooth face at the finish, take a shovel with the back side to the form and push the shovel quickly up and down very close to the boards. This will give *the cement slush* a chance to come on the outside of the concrete. The concrete should remain undisturbed at least forty-eight hours before the form can be removed. Dirt should not be banked against concrete too soon, as this frequently causes the latter to crack.

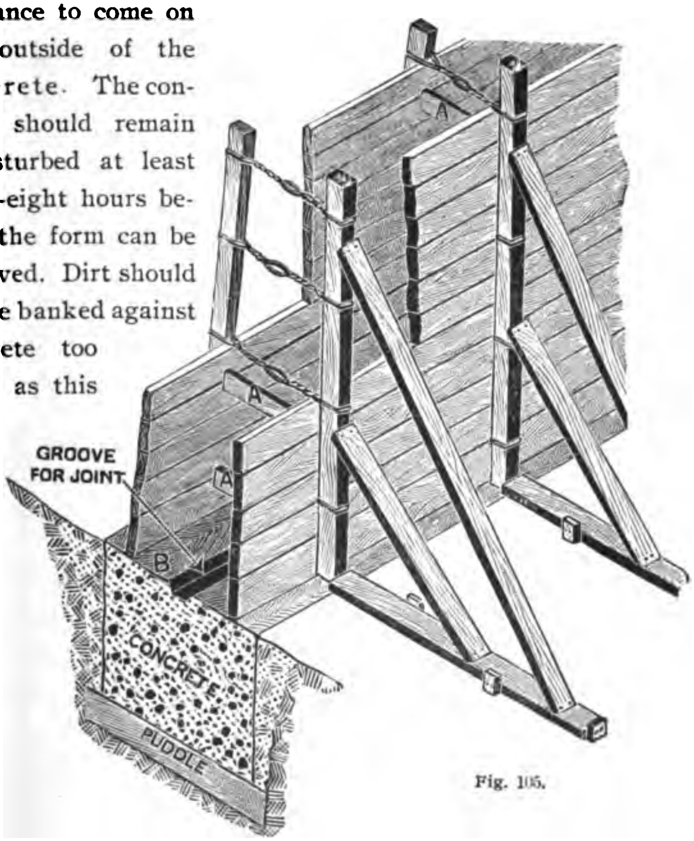


Fig. 105.

An arrangement of forms for erecting *concrete walls* is shown in Fig. 105. It will be noted that the form is braced in three places, besides being wired with, say, No. 12 steel wire. The braces AA are loose or simply tacked into position, being removed as the wall is built up to them. The boards should not be nailed very securely to the framing, and the whole does not call for skilled carpenters to erect it.

Notice should be taken of the puddle filling the bottom of the footing trench in the cut, and that the footings extend several inches each side of the wall. The groove marked B is made with a strickler or even a spade, so that each succeeding layer shall dovetail into that preceding.

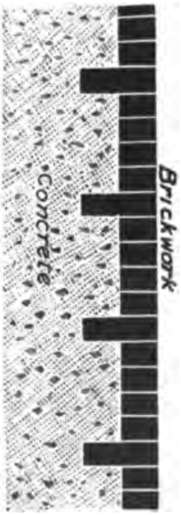


Fig. 106.

Fig. 106 shows a useful application of concrete for *a retaining wall* of moderate height. A half-brick wall, with a header course to every four or five of stretchers is built at a suitable distance from the face of the excavation, and the intervening space is filled with concrete, thus avoiding the necessity of building a "form," and adding a neat finish to the face.

Concrete, although generally erected in the monolithic form, is also made into blocks of rectangular or other desired shape, and is then built up in the same manner as stone-masonry. Other industries employing concrete exist especially in the manufacture of hollow bricks for ventilators, door and window mouldings, gate posts, and similar architectual forms. The engineer also uses this method of construction where very large blocks are required, as at Dover Harbor, Eng., where solid blocks weighing 50 tons each are made and used by the hundred.

Allied to concrete is what is properly termed *artificial stone*, in which the natural chemical construction of building stone is closely reproduced. This material serves conveniently for the cheap reproduction of similar pieces, such as flag stones, chimney pieces, door lintels, vases and numerous other details, for which its homogeneity, good appearance and durability proclaim its fitness.

If possible, foundations should rest on hard pan, gravel or hard clay. Made ground should be shoveled out for a depth of at least 12 inches below the bottom of the foundation and rammed as hard as possible. The 12 inches should then be filled with clay puddle, well rammed in place.

"Neat cement," as specified in tests, means fine cement without moisture or admixture of any kind.

To test cement from barrels, draw out samples from the middle of the barrel with an auger.

Portland cement should be spread on a floor under cover, and exposed to the air, being turned over daily for four or five days; this promotes soundness, as the air slakes any uncombined lime present.

It is necessary that the materials be free of earth, peaty or clayey matter, or very fine sand.

Stones for forming "*the aggregate*" in concrete should be washed to remove dust and dirt which would prevent the adherence of the cement.

The larger the stone used in making concrete, the more it will shrink.

Pure or fat limes, while good for mortar, should never be used for lime concrete, the process of setting being different with the two materials.

POINTS RELATING TO CONCRETE.

Too much water should not be used in mixing, but still it is necessary to mix concrete which has to be water-proof, distinctly wet.

Salt water may be used in mixing if the cement is of the highest quality.

To color concrete it is desirable to add the coloring matter to the mass, using ground natural stone or mineral oxide for the purpose, as they do not weaken or damage the setting properties, but add to the strength of the finished product.

It is always better practice to mix concrete by machine whenever possible; the ingredients get more thoroughly distributed throughout the mass, and the process is much more rapid.

Roman cement concrete should be mixed rapidly and laid at once, as it sets quickly.

Concrete should be dumped in the form as rapidly as possible after mixing.

Careful and efficient ramming is essential; it is sufficient when the water stands on the surface.

The mixing board, shovels, etc., should be cleaned whenever the mixing is suspended or when knocking off at night.

"*The aggregate*" is a most familiar term used by builders and workmen to indicate the combination produced by the mixture of the sand and stones, which form concrete when the cement is added.

Liquid concrete or grout should be as thin as gruel for most purposes (say cement 1 part and sand 2 to 5 parts, according to the nature of the work). It is used with advantage in pouring out beds and joints of massive stone or concrete blocks in foundations and walls.

REINFORCED CONCRETE.

Reinforced concrete, sometimes termed *ferro-concrete*, and *armoured concrete*, is a system of construction, shown in Fig. 107 devised by various French engineers, notably M. Hennebique, in which cement concrete is reinforced by an *internal structure of steel rods and braces.*

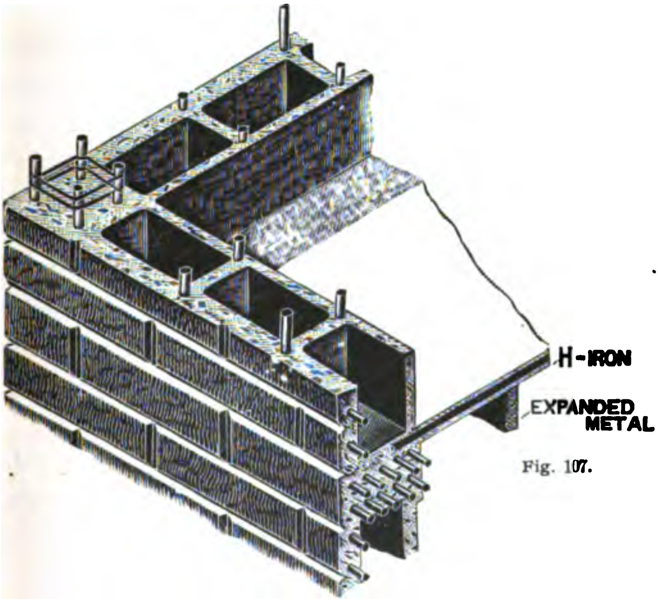
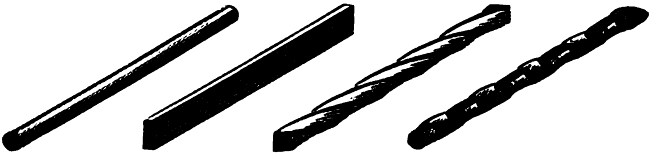


Fig. 107.

Many complicated calculations are involved in determining the dimensions of this type of construction, but its general principles are, (1) that the concrete takes compressive strains alone, and (2) the steel work is calculated to bear all tensile stress.

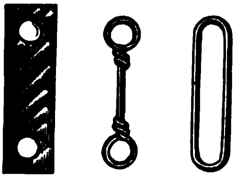
The assumptions are, a safe working compression load of 350 to 500 lbs. per square inch for the concrete, and 50 lbs. tensile strength, while the steel can be loaded to from 12,500 to 16,000 lbs. per square inch. The lower limits represent the best practice.

REINFORCED CONCRETE.



Figs. 108-111.

The whole of the steel work is embedded in concrete mixed in the usual manner, and the construction is generally *monolithic ;* that is, the whole of the structure is built up as a solid mass, each bed of concrete, after ramming, being thoroughly wetted so that the next layer may thoroughly incorporate with it, the various layers being added to one another as rapidly as possible consistent with good workmanship. The appearance of the work is as shown in Fig. 115.



Figs. 112-114.

Columns are reinforced by perpendicular rods, with spiral outside bands to prevent buckling of the concrete ; *short beams* have usually a few tension rods near their lower side ; *lintels* over large openings present the most difficult problem in reinforcing, requiring the rods to be arranged in the form of a truss.

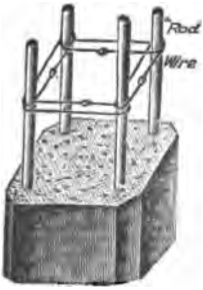


Fig. 115.

The steel bars, Fig. 108-111, which form the reinforcement, are united by welding to form pieces of the desired length, and are built carefully into a skeleton or cage in the desired position.

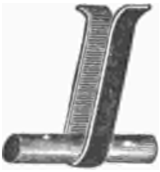


Fig. 116.

REINFORCED CONCRETE.

French engineers use bars of round or rectangular sections, while, in the United States spirally-twisted square bars or those of corrugated sections are in vogue. The use of the latter sections is to provide better adhesive power between the concrete and the steel. It is self-evident that if the steel bars, through vibration or other causes, become slack in the concrete, they will be of no use as a purpose of reinforcement. To assist this adhesion between the two materials absolute cleanness of the steel work is imperative; there should be no rust upon the bars; oil and grease is decidedly dangerous. The sand blast has been used with marked success.

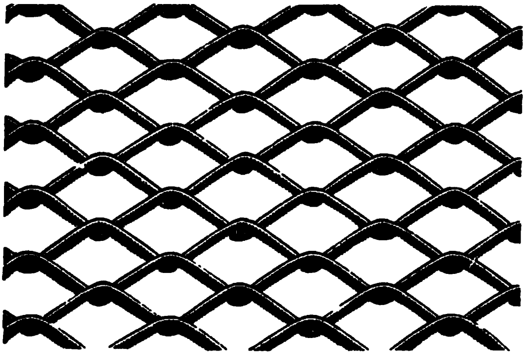


Fig. 117.

In *concrete bridge building*, beams of H sections are used, tied laterally by angle irons, whilst for short spans ordinary flatfooted T-rails have been utilized. In the construction of floors and beams some engineers have substituted pipes for bars.

Wherever two rods come into contact with one another, it has been found to be good practice to lash them together with stout steel wire, wound around when at a bright red heat. At distances varying from eight to twenty

REINFORCED CONCRETE.

inches, the parallel rods are tied to one another by means of forged links, straps and wire loops, as in Figs. 112-114, in many cases the tie-bars being simply hooked over both members while red hot. The stirrup, Fig. 116, is utilized to transmit strain from the part in tension to that in compression. These details are illustrated on page 130.

For walls, partitions and the like, the reinforcement often consists of *sheets of expanded metal*, similar to Fig. 117: This is a trellis or grating of steel perforated without cutting away any portion of it, the projecting edges around the meshes being expanded and curved outwards and backwards, thus affording splendid adhesion to the concrete. *The length of the sheet is increased from six to twelve times by the process*, while the width remains unaltered. This metal is used with a sectional arc of 1/200 that of the concrete, but is not suitable for beams; and when

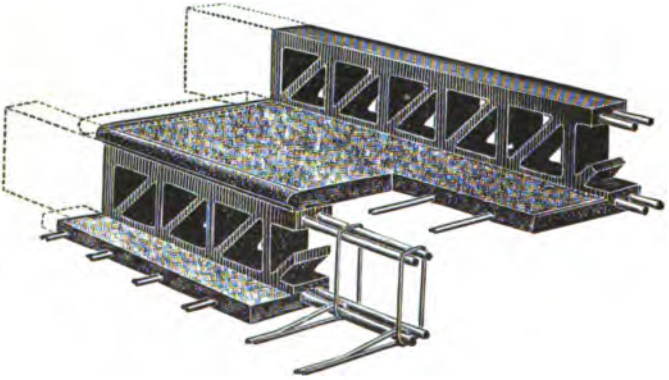


Fig. 118.

NOTE. *Fireproof solid partitions* are built in the same manner as a wall, between two "face forms." In the middle of the mass of concrete are incorporated *continuous sheets of expanded metal*.

RODS IN ARMOURED CONCRETE.

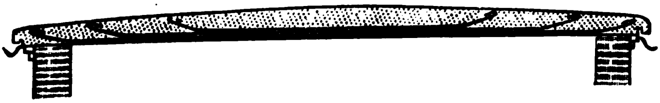


Fig. 119.

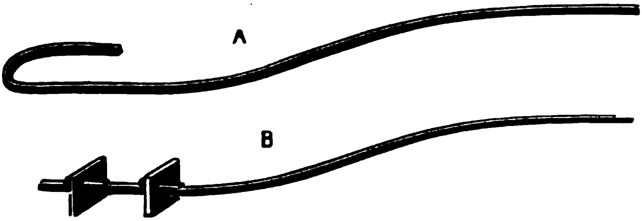


Fig. 120.

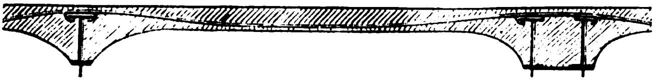


Fig. 121.

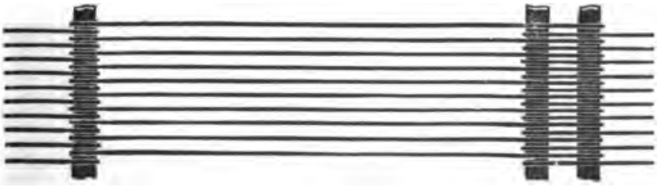


Fig. 122.

CONCRETE PILES.

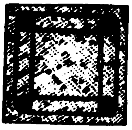


Fig. 123.

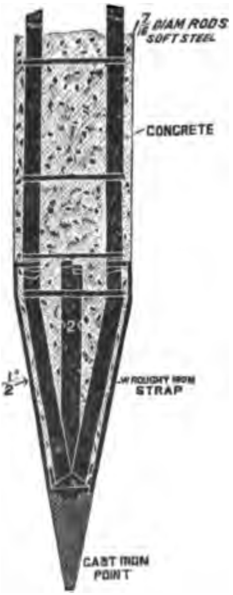


Fig. 124.

made into floors, needs to be reinforced by ordinary steel joists. Fig. 118 represents the Visintini system, used for girders and beams, a concrete made of one part cement, one and one-half sand and three and one-half broken stone reinforced with one-half inch steel bars. For columns, the concrete used is one cement, two sand, four broken stone with one inch vertical steel rods.

As further examples of this construction illustrations are given of a slightly vaulted roof, Fig. 119, on the "Eggert" system of reinforcing; and of an arched floor, Fig. 121 on the "Koenen" principle.

The "*Eggert*" arming consists of square bars, as shown enlarged in Fig. 120. The hook A, is that adopted with roofs, floors, etc., of small span, and will be recognized as that employed in the construction of the roof, Fig. 119. For heavier floors, or those designed with a relatively large span between supports, the anchor B is used, the flat plates being keyed on to the bar at the desired point. These devices serve to reinforce the concrete, and to distribute strains equally over its whole bulk, the hooks or anchors transmitting tensile strains into the zone of compressive force.

The "*Koenen*" reinforcement, as shown in plan in Fig. 122, consists mainly of curved iron rods hooking over the supporting I-beams. This particular floor is known by some as the "arched plate," and is typical of the methods adopted with regard to modern fire-proof floors.

CONCRETE SHEETING PILE.

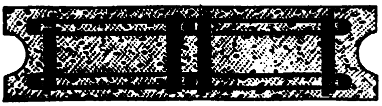


Fig. 125.

In constructing pillars, especially where economy of floor space is desired, it is recommended to use two per cent. of vertical rods with three per cent. of spiral hooping wound on a pitch of about one-eighth the diameter of the work, the percentage in each case referring to the mass within the hooping. This will sustain a safe load of 1,000 lbs. per square inch.

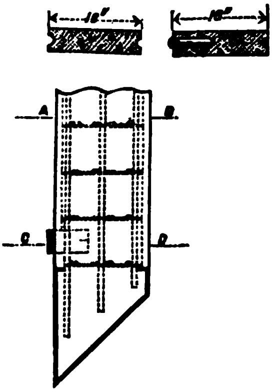


Fig. 126.

It is evident that great care must be exercised in proportioning the amount and nature of the reinforcement, to obtain a proper distribution of the stresses, but it is unnecessary to adhere to the practice, occasionally demanded, of making the steel work strong enough to sustain the whole load, and then adding the concrete. The usual practice is to give a reinforcement of two to four per cent. of steel in the mass. *Ferro-concrete occupies only one-third the space of stone masonry for equal strength.*

Figs. 123-124, illustrates a pile built of reinforced concrete, which is impregnable to the attacks of the *teredo*, and possesses the resilience and elasticity of timber piles. The pile is made in a vertical timber mould, one side of which is left open for working. The shoe is first put in, the various parts of the armouring built into place, and then the mould is carefully filled with concrete, the open side being gradually closed up, six inches at a time, as the ramming proceeds. The moulds may be stripped within forty hours, but the piles must be allowed to remain drying for a month or six weeks before driving. A cap must be fitted on the top of the pile when driving, with sawdust between the cap and the pile to save jarring and fracture. It is best to use a heavy monkey with short blows.

Fig. 125 represents the section of a ferro-concrete sheet-pile, while its elevation and cross sections are given in Fig. 126, clearly showing the arrangement of the spur which cleans out the groove on the pile previously driven, and guides while driving. These grooves are afterwards washed out with a jet of water and then filled with cement grout, locking all together.

Hollow Concrete Building Blocks. Single blocks are made of concrete as large as 8 feet long, and 8 inches wide, and 10 inches thick, reinforced by steel rods. Blocks are rarely made longer than 6 feet without reinforcement. Single-piece hollow blocks are made 20 inches to 32 inches long by 8, 9 and 12 inches in depth and width to make the full thickness of the wall. Two-piece blocks are made, as the name implies, for face and back walls. In making hollow concrete blocks the following directions are given: —

NOTE. "After the materials are mixed dry, water should be added from a sprinkling can till the mass is of a uniform color and sufficiently wet to retain shape when squeezed in the hand. The quantity of water required will vary with the condition of the sand and percentage of humidity in the atmosphere. Shovel the mixture into the mould in small quantities, meanwhile constantly tamping. Remove the block on the pattern to a place under cover, where it shall remain for at least one week (two weeks shows greater strength); sprinkle the block next morning, and twice daily for one week, when the block may be safely used in building."

MILLWRIGHT'S TOOLS.

The woodworking tools used by the millwright in constructing heavy timber framing are those used by the carpenter.

The *felling axe* Fig. 127 is used for cutting down trees, or for dressing logs.

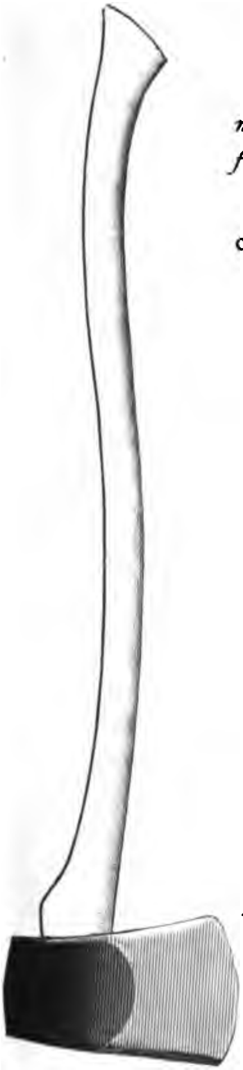


Fig. 127.

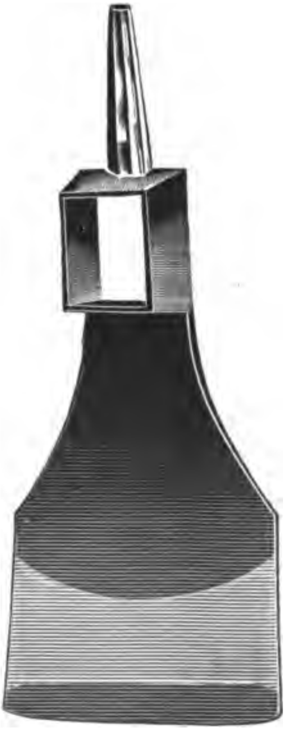


Fig. 128.

MILLWRIGHT'S TOOLS.

The broad axe, Fig. 129, is used for dressing the sides and ends of logs or heavy planking, while *the shipwright's adze,* Fig. 128, page 137, is a most efficient tool for removing large portions of wood and shaping the log. Owing to the manner in which it is held, with the workman standing upon or astride the log, and cutting between his feet, it is possible to hit a powerful blow, or to make a series of nicely-gauged strokes which will dress the material evenly to a chalk-line.

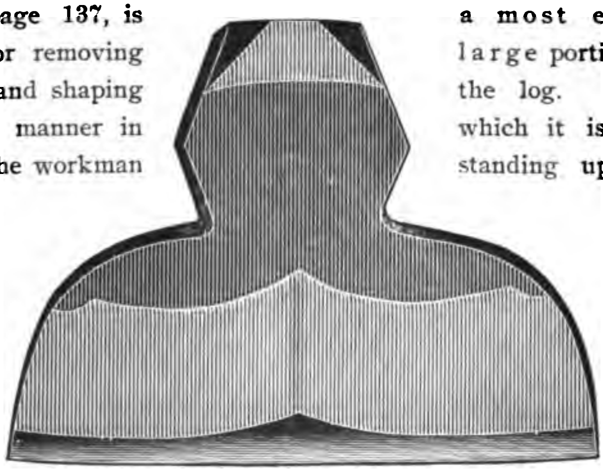


Fig. 129.

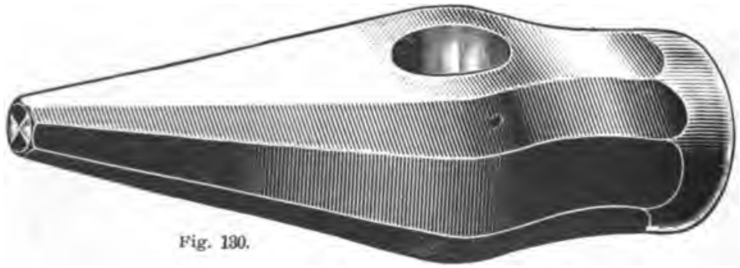


Fig. 130.

NOTE.—If the workman stands on the log, it is better for him to keep his right foot on a small loose piece of wood about an inch thick which he slides along as the work progresses, so that, if the tool slips, he does not cut his foot. Practical experience dictates this suggestion.

MILLWRIGHT'S TOOLS.

Logs, beams, and large timber generally, are sawn into lengths by means of the *cross cut saw*, Fig. 131, which is operated by two men working upon either side of the piece of timber.

Smaller varieties of this useful instrument operated by a single workman, are used for many purposes; the *rip-saw* is perhaps the most familiar of all these and used for sawing up planks and scantlings; the *tenon saw* in which the back of the blade is stiffened by a bar of steel or brass to ensure rigidity and accuracy of cut when forming tenons for mortise joints; the *frame saw* in which a narrow blade is mounted upon a skeleton framework for use in cutting out scrolls and involved patterns, etc.

To avoid unnecessary lifting, the *cant-hook*, Fig. 133, is used to shift the logs along the ground or to roll them over, the swinging hook engaging in the wood and affording a fulcrum for the lever. When the lever is shod with a pointed socket, it becomes the *peevy* of the lumberman, so named from its inventor.

To assist further in moving logs about, *rollers* as in Fig. 132 are provided; these greatly facilitate the handling of the timber, as it is not practicable to keep sufficient help standing by all the time to lift the logs about. These idle rollers are termed *dollies* or *dawdlers*.

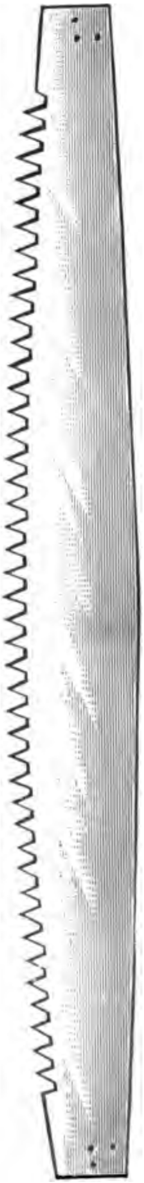


Fig. 181.

MILLWRIGHT'S TOOLS.

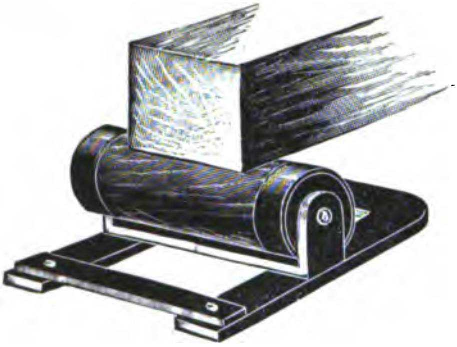


Fig. 132.

Fig. 133.

The *maul*, Fig. 130, is a characteristic carpenter's hammer, used for driving spikes, wedges, keys, in fact anything wood or iron that requires a good blow.

The *tool chest*, Fig. 134, containing an assortment of carpenter's and joiner's tools, is a necessity for the millwright. He will require a trying or fore, jack and smoothing planes, hatchets, gimlets, chisels and gouges, a brace and bits, augers, a drawing-knife and spoke-shave, rip, tenon, key-hole and compass saws, a glue pot, together with vises and clamps for holding the work, gauges for marking it off, nails and screws to fasten it together. and hammers and screw drivers to apply the latter.

TOOL CHEST.

Many small tools, already described in connection with other trades, also find a place in the woodworker's tool chest.

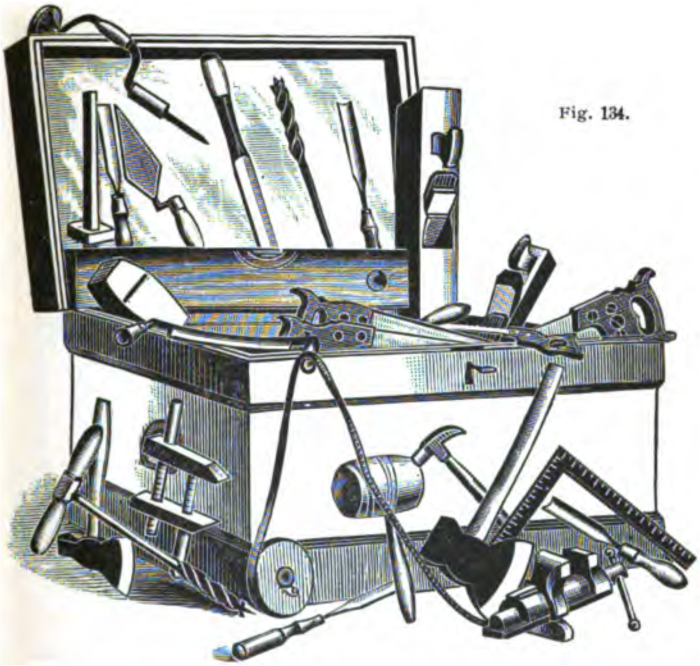


Fig. 134.

The *treadle grindstone*, Fig. 136, represents a useful type for service in erecting or outside work, where the power driven stone is not available.

The yellowish-gray stones from Nova Scotia are to be recommended for grinding machinists' tools, and may be obtained of all varieties of grit and texture from hard and coarse to soft and fine. For wood working tools alone, a pale bluish stone obtained from New Brunswick or the State of Michigan, is soft and sharp with a medium to finest grit, and fulfills most requirements.

For dealing with bright or finished work *a mallet*, such as shown in Fig. 135 is requisite.

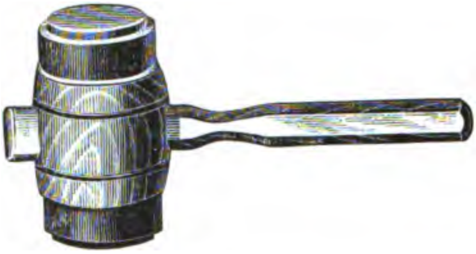


Fig. 135.

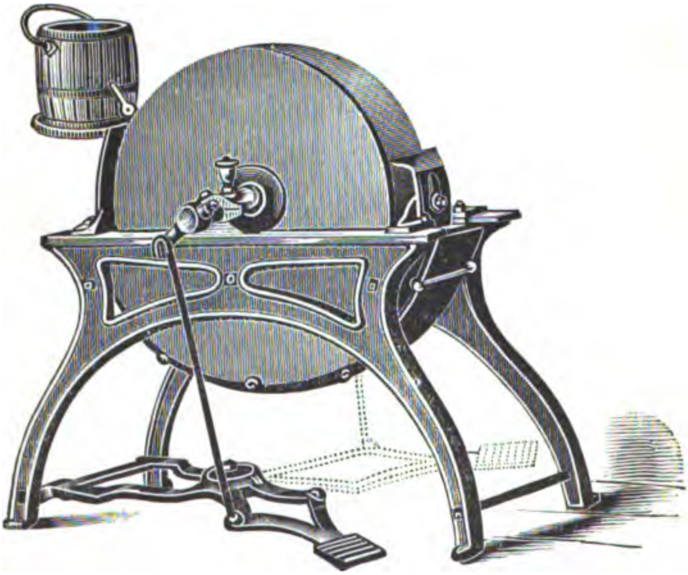


Fig. 136.

Note.—It is scarcely necessary to remark that the drip-keg should always supply a plentiful supply of water as the stone is in use, but it is unwise to let water remain in the trough, as it does the stone no good.

BLACKSMITH'S TOOLS.

Oilstones, Fig. 137, are of different textures depending upon their origin. The buff and grey stones from the State of Arkansas, known as Washita stones, are the better for carpenter's edge tools, but for razors, surgical instruments and fine articles it is wiser to use the dark grey Turkish stones.

The work of the millwright calls for a knowledge of *forging or blacksmithing*; that is, shaping wrought iron or mild steel to the desired form while at a full red or white heat by means of blows with hammers and suitably shaped implements, or welding separate portions of these materials together whilst at a white heat, when the metal is sufficiently heated to be in a semi-fused condition, permitting the different pieces to coalesce and unite under the hammer.

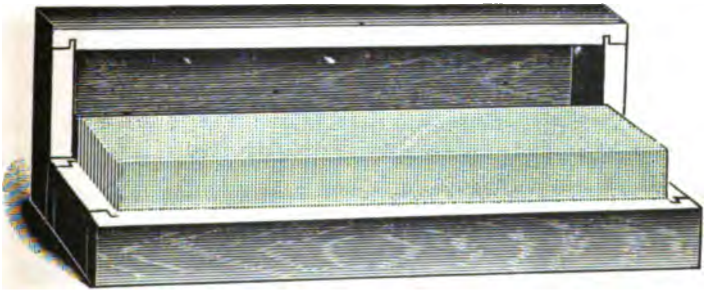


Fig. 137.

The bolts, keys and other fastenings of the millwright's framings frequently require to be forged at the site of erection, especially with timber work; bent or defective pieces require to be made good; piecing, especially of levers and stays has frequently to be resorted to. The millwright, erector and carpenter should all know something of the art of iron working which enters into so many of the details of a structure.

BLACKSMITH'S TOOLS.

The sections of iron and steel dealt with by the smith are few and simple, being generally either *round*, *square*, *or a rectangular bar;* hence there are no complicated tools to deal with the work. The only cutting tools used by the blacksmith are those actually employed to sever the forging from the stock or to remove extraneous metal, the chief art of smithing consisting in reducing the sectional bar to the desired form or *drawing it out.*

Where sharp changes of section occur, as in the throw of a crank shaft, or with collars on a shaft, necessary material is *welded* upon the forging. These characteristic processes are the natural consequence of the pronouncedly fibrous nature of wrought iron, and the slighter amount of fibre developed in mild steel by rolling.

Tongs of various shapes are used to hold the iron bars which are being operated upon, and the following may be taken as representative of the many types to be found. Fig, 138 is the *flat bit close-mouth* tongs for holding flat bars of relatively thin dimensions; Fig. 139, the *hoop* tongs for holding thin strips or hoops at right angles. Fig. 140 shows the *round-bit* tongs used with work of circular section, Fig. 141 exemplifying a type of pliers. The curved space between the rivet and the jaws of this last tool is for the reception of bolt heads, collars and enlargements on the work desired to be operated upon. A combination of Figs. 140 and 141 is very common.

The *anvil*, Fig. 142 and the *swage block* Fig. 143 are masses of iron upon the surfaces of which the smith beats the heated plastic metal into the desired shape. The anvil is usually of wrought iron with a steel face. The *beak* serves as a mould for bending curved portions of the work, while near its root is a portion of un-

BLACKSMITH'S TOOLS.

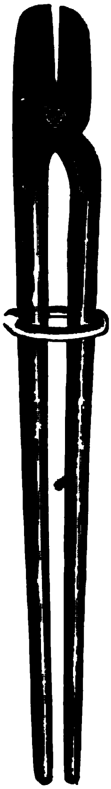
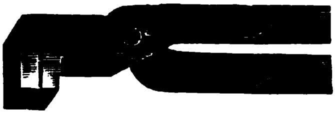


Fig. 138.



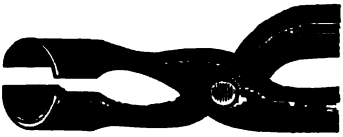


Fig. 140.

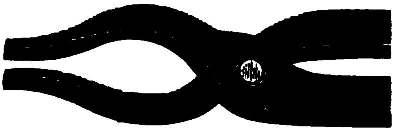


Fig. 141.

faced iron on which bars may be cut off without fear of encountering the hard steel. The end furthest from the beak is perforated with a square hole, known as the *hardy-hole*, for the reception of various tools used in combination with their counter parts held in the hand of the smith.

To reduce the red hot bar it is drawn out between the *bottom fuller*, Fig. 148, which is simply an inverted wedge, and the *fullering tool*, Fig. 144, *which the smith holds in one hand* while he manipulates the tongs holding the bar with the other, his helper or striker, hammering the head of the top fuller with his *sledge.* Fig. 145 represents a *curved fuller* for working close up to a collar or boss on the forging.

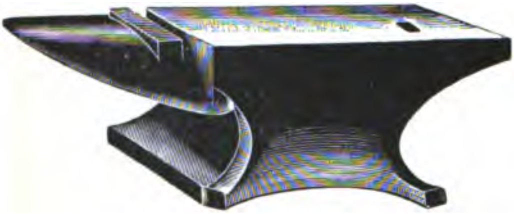


Fig. 142.

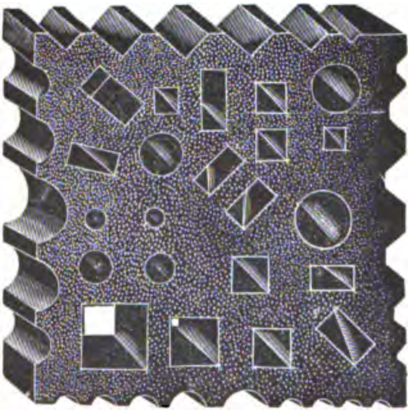


Fig. 143.

After forgings have been drawn down with a series of alternate furrows and ridges made by the fullering tools, they are wrought to a smooth surface by means of the *flatter* or flatting tool, Fig. 146, or the *sett hammer,* Fig. 147; this last is also used to straighten out work bent whilst being forged.

Round iron is similarly shaped between the *anvil swage* Fig. 149, and the top swage, Fig. 150. Not only is the work smoothed and finished by this means, but stock is very frequently reduced in size or fullered to the required dimensions by the same means.

A pair of swages or fullers are often fixed at the extremities of a flat steel bar bent over to form an elongated flattened ⊃; this combination is known as a *spring tool,* and is much used in connection with steam or power hammers.

BLACKSMITH'S TOOLS.

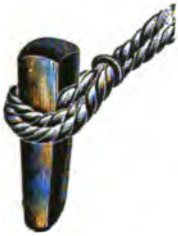


Fig. 144.

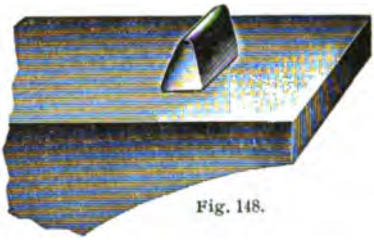


Fig. 148.

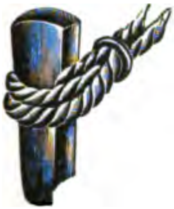


Fig. 145.

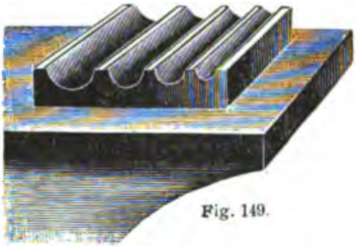


Fig. 149.

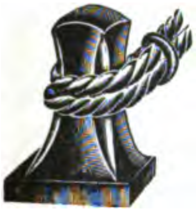


Fig. 146.

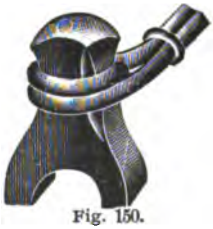


Fig. 150.

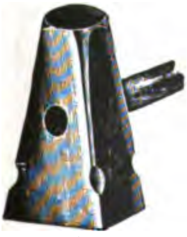


Fig. 147.

Note.—It will be noticed that most of these hand tools are provided with handles of twisted cane or osier. This is to prevent jarring of the smith's wrists as he holds his tools under the heavy blows of the sledge hammer. Iron wire is also used, and holds the tools stiffer than osier, being generally utilized for cutting tools.

ERECTOR'S TOOLS.

In cutting off lengths from bars, or crop ends from forgings, chisels are used, which are termed *hot* and *cold sets*, accordingly as to whether they are shaped or ground and tempered for dealing with the iron in its heated state or not. Fig. 151 represents a *hot set*, the cold set being less acute in its taper and of a softer temper so as to bend rather than break. These sets are used in conjunction with the *hardy*, an anvil tool greatly resembling the *bottom fuller*, Fig. 148, except that it has a sharp chisel point, where the latter is rounded or convex.

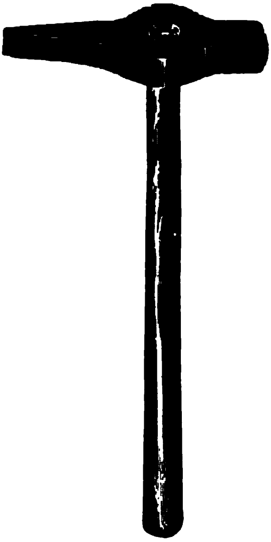


Fig. 151.

The *swage block*, Fig. 143, which is in ordinary use, is generally of cast iron. The various grooves around its edges act as so many bottom swages, while the many holes with which it is pierced serve as a "heel" for bending bars, or to hold forgings which it is desired to "set up" or enlarge by battering on one end, as in preparing for a butt weld.

The tools next in order are peculiarly the appliances of the outside workman, the millwright and the erector, as they have to deal with beams, girders and plates which have to be incorporated into the framing or machinery which they may be putting up. Bars have to be cut to lengths, holes have to be made, both after measuring off on the actual work itself, and often far from the machine shop. A selection of portable tools for outside use is now described.

ERECTOR'S TOOLS.

The *parallel vise*, Fig. 152, in use by nearly all trades, is a handy tool for erectors, as it may be mounted on any convenient plank, or fixed easily on a temporary bench. The jaws opening parallel, make it more convenient for holding large objects, such as engine brasses, etc., than the ordinary bench vise.

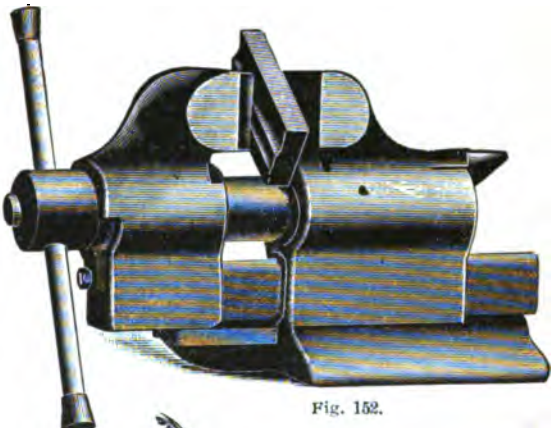


Fig. 152.

The *hydraulic screw punch*, Fig. 153, is a very simple portable appliance, without valves or pump. The chamber is filled with water or oil, and by turning the screw in, the ram or plunger of the punch is forced down, as the fluid is incompressible. To disengage the punch, the screw is turned back, when the ram is forced back.

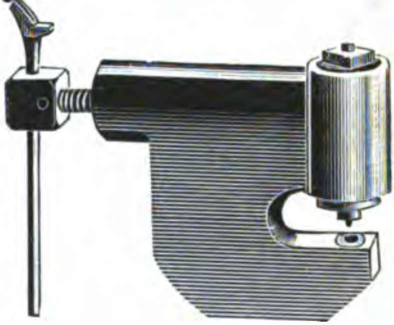


Fig. 153.

Fig. 154 represents a portable hand punching device called a *bear*, whose use is sufficiently indicated by the cut.

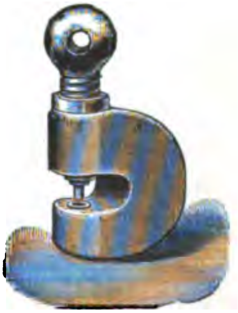


Fig. 154.

ERECTOR'S TOOLS.

The ***hand punching machine***, Fig. 155, is an erector's tool, for punching holes in plates, angle bars, etc., on the site for erection. The power is obtained through the two toothed cams, which constitute a toggle joint, thus exerting a heavy pressure when the brake-handle is pushed down, which pressure is further multiplied by the lever.

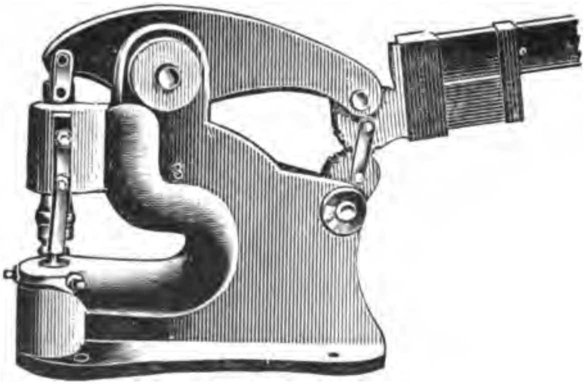


Fig. 155.

A *screwing outfit* of stocks, dies, taps and wrenches, similar to Fig. 156, is an important item in the erector's kit of tools. Taper or first taps, making three in a set, should be provided, in view of the numerous rough holes met with in outside work. For bolt threads, the sizes increase by eighths from ¼" to 2"; for gas threads, on pipes, etc., they range from ½" by quarters to 1½," and by half inches to 3."

Fig. 157 shows a good modern type of the *ratchet drill.* This is a hand boring machine, wherein, by means of a pawl, engaging in the teeth of a ratchet, the workman by vibrating the lever is able to rotate the drill. The necessary "heel" or fulcrum for

ERECTOR'S TOOLS.

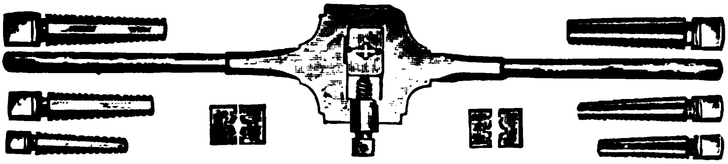


Fig. 156

applying the drill is given by a post or Z-shaped iron, which is bolted or clamped to the work on which it is desired to operate, the centre-point of the ratchet drill abutting on the cross arm of the drill post or Z-iron. The drill illustrated can be turned in either direction, as will be seen by referring to Fig. 158, which is a section. As it stands the ratchet is out of gear, but on pressing the pawl-piece down, the hidden V-shaped detent engages with the upper notch, and consequently the pawl is so held that the ratchet works clock-wise or from left over to right; with the V-detent in the other notch, the drill works anti-clockwise.

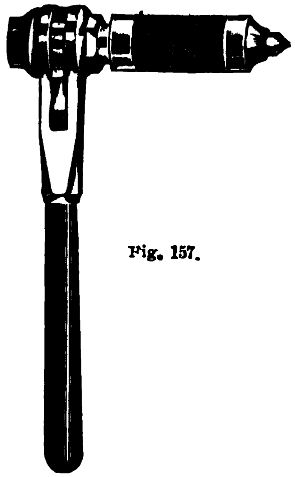
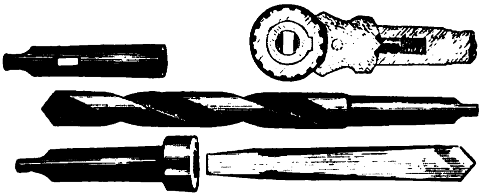


Fig. 157.

NOTE. In many cases the ratchet drill has been superseded by a portable drilling outfit, in which a flexible shaft transmits power from a sort of hand winch to a rotary drilling machine which can fit into the same restricted dimensions as the ratchet. Of course, wherever power is obtainable, the pneumatic or steam-driven drill is daily gaining favor.



Figs. 158-162.

ERECTOR'S TOOLS.

Figs. 158-162 show a *twist drill* and a common *flat drill* for use with the ratchet together with their respective sockets which hold them in place.

In putting up iron framing, a *boiler-maker's spanner*, Fig. 163, is much in use; it is longer and more powerful than the ordinary type, and its shank is tapered to serve as a toggle for bringing the bolt holes of two pieces fair with one another. The *drift pin*, Fig. 164, is much used for the purpose of "fairing" bolt or rivet holes, that is drawing the holes in one flange or plate exactly in a line with those of its neighbor, so that the bolts may be readily inserted.

The *hack-saw*, Fig. 165, is more used now than ever. Formerly it served to cut brass alone, or very light work; but is now to be seen in use cutting up quite heavy bars, even rails.

Fig. 166, the *bridge builder's wrench*, is an ingenious tool, provided with an internal mechanism like a ratchet drill, so that a nut can be turned either way without removing the spanner or risk of dropping the nut, suitable for work carried on at an elevation, where accidents are frequently caused by falling articles. By substituting a drill socket, the wrench can be transformed into a ratchet drill.

The *monkey-wrench*, Fig. 167, forms a convenient adjustable or shifting spanner for dealing with work where there are several different sizes of nuts; more especially with bright finished brass work or steel, where it is desirable not to strain the corners or mark the nuts.

Fig. 168, shows a *ball-bearing screw jack*, in which the power is considerably multiplied by working the lever on the ratchet principle. The ratchet spindle drives the jack-shaft through a bevel train, the bevel wheel running on ball bearings, thus

ERECTOR'S TOOLS.

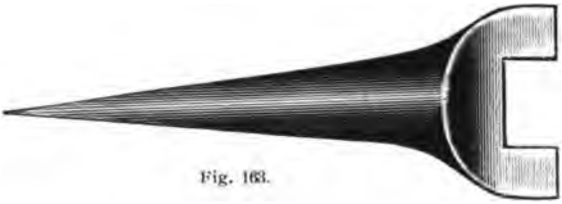


Fig. 163.

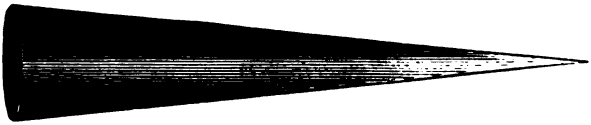


Fig. 164.

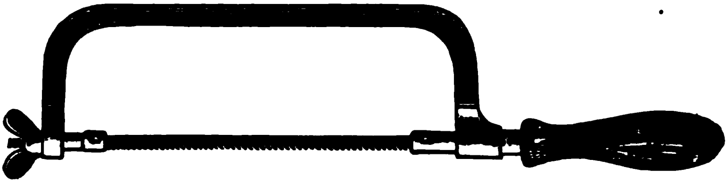


Fig. 165.

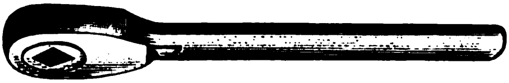


Fig. 166.

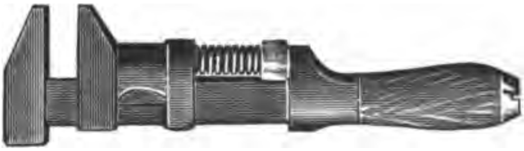


Fig. 167.

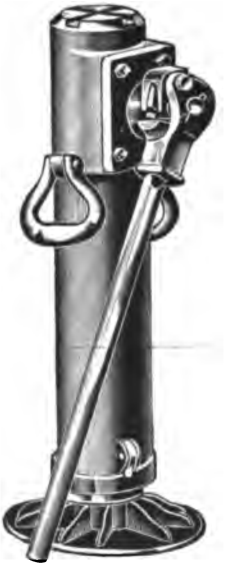


Fig. 168.

reducing friction to a minimum. The notches on the crown of the jack are made to receive a stout iron hook in case it is desired to lift anything already on the ground. The jack illustrated will lift 20 tons through 20."

Fig. 169 is a *hydraulic jack*, which perhaps constitutes the seventh simple machine, as by the law of equal transmission of pressure through fluids, the pressure per square inch maintained by hand-power on a small plunger worked off the lever is maintained on each square inch of the jack-plunger, thus multiplying the force applied in the ratio between the areas of the two plungers. The power is applied by forcing water between the end of the plunger and the head or case which slides on it; the plunger, already on the ground or on a solid base cannot go down, therefore the outer case rises, *bearing along with it* the object to be lifted. A small screw not shown, which permits water to run from the ram cylinder into the reservoir, controls the descent.

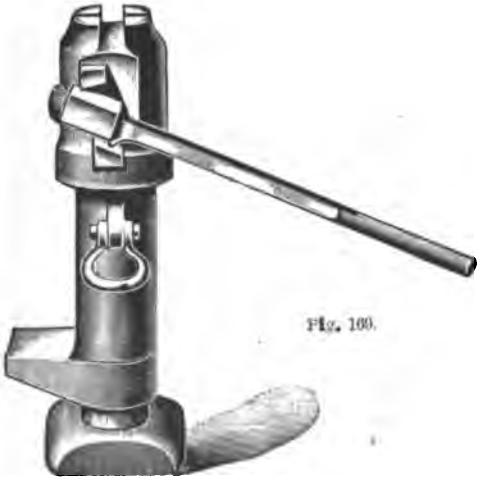


Fig. 169.

THE STEEL SQUARE.

This instrument is also known as *the carpenter's square*, and again, as *the framer's square;* it is beyond dispute the millwright's most useful tool. The skillful manipulation of its various and somewhat intricate markings in practical use indicate a master-builder and millwright. To know its inventor's name and the period of its introduction—now in almost universal use—would be most interesting. It is doubtless a product of the New World—this being a timber country, and in this respect greatly different from Europe with its treeless plains.

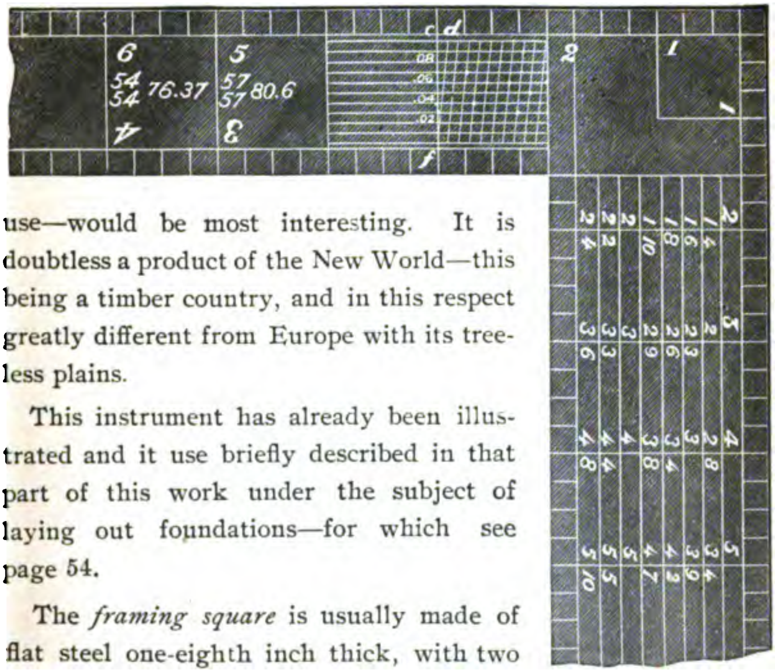


Fig. 170.

This instrument has already been illustrated and it use briefly described in that part of this work under the subject of laying out foundations—for which see page 54.

The *framing square* is usually made of flat steel one-eighth inch thick, with two unequal arms, the longer or "blade" being 24″ x 2″, and the shorter or "tongue" 16″ or 18″ x 1½″. Different makers have devised markings and divisions of varying degrees of utility, but the more generally adopted form is divided along the edges of one side into the customary $\frac{1}{8}$″, $\frac{1}{16}$″, $\frac{1}{32}$″, or $\frac{1}{64}$″, and subdivided on the other side as shown in Fig. 170, for varied applications hereafter described.

The *diagonal scale*, as shown on the tongue near its junction with the blade, facilitates reading off measurements as fine as .01″, or one-hundredth of an inch. The inch being divided into ten equal parts both vertically and horizontally, it follows that the diagonal line *d f* approaches the vertical line *c f* by $\frac{1}{100}$ inch or $\frac{1}{10}$ of $\frac{1}{10}$ at the intersection of each vertical line as it gets nearer *c f*.

The edges of this side of the square are subdivided into $\frac{1}{4}$, $\frac{1}{8}$ or $\frac{1}{12}$ inch, while graduations which make this instrument a calculating machine occupy the middle space on both blade and tongue.

The *brace scale* is that seen on the centre of the tongue, and is used for determining the length of a brace where the *run* on the sill and the *rise* on the post are the same; similarly, it will give the diagonal of a square whose sides are known. The equal numbers placed one above the other represent the sides of the square or the "rise" and "run" of a brace, and the numbers to the right give the length of the brace between shoulders, or the diagonal. Thus in Fig. 170 we see $\frac{54}{54}$ 76.37, which implies that the diagonal of a square with 54″ sides measures 76.37 inches, and that measurement will be the length of a brace having 4′ 6″ run on the beam and the same amount of rise on the post.

The figures in the middle part of the blade constitute what is termed *board measure*, which gives the superficial measure of a board, or more properly, enables the millwright to find the equivalent length of a board, of the standard width of 12 inches, corresponding with the area of the given board. The different horizontal measures give equivalents for boards of each foot in length, from 8 feet to 14. Therefore, in use for boards of those limiting dimensions, the length is sought under the 12 mark, in *every case* and in *all squares*, and following the line occupied in that column to the width figure, where the answer is found.

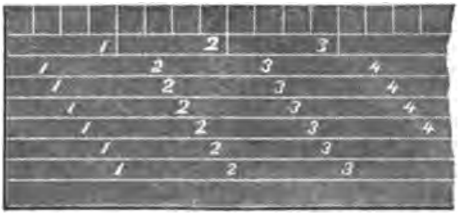


Fig. 171.

Thus: it is desired to find the superficial area or equivalent length of a plank 13 feet long by 15 inches wide;—13 will be found on the sixth line below the 12 mark, and following the line to the right, under the 15 mark, is found 16′ 3″, which shows the length of the equivalent 12″ board to be 16′ 3″, or that the superficial area is 16¼ square feet. Again; it is desired to find the surface of a 10 foot plank 4 inches wide—10 is on the third line under 12; reading to the left we find the answer 3′ 4″ under the width 4″, which is the equivalent length of a standard plank 12 inches wide, or, by transposition, becomes 3⅓ square feet, the area of the 10′ 0″ x 4″ plank. Some squares are marked for board measure as in Fig. 171 without the fractional parts of the foot, the answer being found in a similar manner, to the nearest foot only.

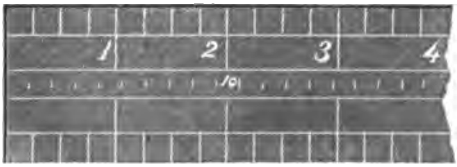


Fig. 172.

STEEL SQUARE PROBLEMS.

The octagonal scale is on the other side of the tongue, opposite the brace measure, and is shown as the short cross-lines (sometimes dots) as in the central part of Fig. 172. The method of use is as follows: when a square log is required to be dressed down into an octagon, a centre line is marked along each side, and from *each side* of this centre line is laid off another line at a distance of as many marks in this octagonal scale as there are inches in the square; these two parallel lines mark the corner to be dressed off. For instance, in making an octagon from an 8" square log, a centre line is drawn on each side 4" from each corner; at each end a distance corresponding to 8 marks on the octagonal scale is laid off each side of these centre lines, a chalk line is run from one end of the log to the other, and these chalk lines indicate the corners of the octagon.

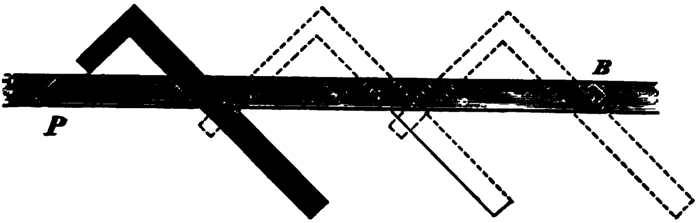


Fig. 173-Problem I.

PROBLEM I.—*To find the length and bevel of a brace or rafter when the rise and run are given.*

In the first case a brace is taken in which the rise and run are equal, forming what is termed a "square brace." For example, the rise and run being given as 2' 6" or 30", they are divided into three parts each of 10 inches. The square is then laid on the stick as in Fig. 173, with the 10" mark on both blade and tongue coinciding with the gauge line *l*; a line drawn outside the tongue at *P* forms the *bevel* for one end of the brace. Another mark is made where the blade crosses the line *l*, and the square is moved along until the 10" mark on the tongue occupies the place where the 10" mark on the blade was before.

This operation performed once more, or in all three applications of the square, gives the exact length of the required brace, and the bevel for the other end can be marked off as at *B*. It will be evident to the student that other factors of 30 can be taken for marking off the brace, as 7½" taken four times, 6" and 6" applied five times, or 5" measured off six times will give the same total length and the same bevels.

In the second case, the rise and run are supposed to be unequal, therefore care must be taken, in subdividing into proportional parts, that the number taken is proportionate to both the longer and the shorter dimensions. The *shorter* rise or run is subdivided into the chosen number of equal parts and the length marked off on the *tongue* of the square, the *longer* rise or run, having been subdivided into the *same chosen number* of equal parts, the length of each is also marked off on the *blade* of the square; the process of marking off following as in the preceding case of the square brace. Thus with a rafter having a run of 12 feet and a rise of 8 feet, it will be necessary to mark 24" on the blade and 16" on the tongue, applying six times to mark off the proper lengths and bevels. A little consideration will show that 18" and 12" might be used eight times, or if needs be, 12" and 8" might be used twelve times, it being only necessary to use factors which are within the limits of the tongue or blade, and which are a definite "common measure" of each number.

STEEL SQUARE PROBLEMS.

The lengths which have been found are the distances *between the shoulders* of the braces, and the *tenons* must be allowed for beyond this. The manner of laying off a tenon is illustrated at *B* (Fig. 173). In the engraving is shown also the method of marking off a brace which requires to be *let into* the post or beam; a line *l* is marked off at the requisite distance, say ½″, from the edge of the stick, and the length of the brace is measured off along this line *l*. Should the brace sit flush on post or sill, the length must be worked off from the *edge* of the stick.

PROBLEM II.—*To find the bevels and widths of sides of a square hopper.*

In the diagram, Fig. 174, the large square represents the upper edges of the hopper, *as seen in plan*, and the smaller square is the interior of the base or lower edge of the same. To find the width of a side or end, from base to top, or what really is the slant height of the hopper, the distance *a b*, or half the difference between the two squares, is taken as the *run* on the *tongue* of the square, the perpendicular height *a d* as the *rise* on the *blade*. Thus, in a similar manner to finding the length of a brace, the diagonal across the square gives the width of the hopper side or end.

To cut the ends of the sides forming the corners of the hopper, the slant height or width *b d* is taken on the *blade*, and the run *a b* on the tongue, the latter measurement giving the amount by which the board is longer each end at the top than at the bottom.

With mitre joints at the corners, the outside edges will be longer than the inside, therefore if the hopper has to be made to a definite capacity, all measurements must be made on the *inside edges* of all boards, and the mitre bevels struck outwardly from these marks. With butt joints, it will be necessary to make the sides longer at each end by the thickness of the end boards.

To make the top and bottom edges of the hopper horizontal, the perpendicular height *a d* is taken on the *blade*, and the run *a b* on the *tongue*, a line from the latter giving the proper angle for the cut.

With large hoppers, especially those with butt joints, it is frequently requisite to place stiffening pieces in the corners; a further reference to Fig. 174 will show the method of determining the lengths and bevels of these.

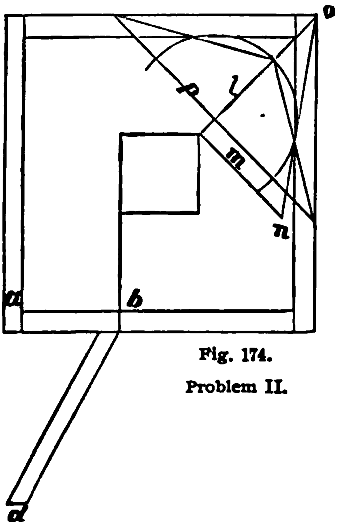


Fig. 174.
Problem II.

The diagonal line *l* is drawn from the inside to the outside square, and is taken as the *rise;* the line *m* is set off square with the rise and made equal to *a b*, the *run*, therefore, *o n* the diagonal is equal to the *length* of the corner piece, as has been seen in measuring braces. To determine the angle of the bevel or backing of this stiffening piece, draw a line *p* at right angles to *l*, at any convenient place, from the point of intersection as centre, describe a circle just touching *o n;* a line drawn from the point where this circle cuts *l* through the point where it touches *o n* gives the requisite bevel.

Another method is to measure the diagonal of each square, subtract the smaller from the larger, and half the remainder is the *rise* taken on the *blade* of the square; the *run* or half difference in side of the squares is taken on the *tongue*, and so the length of the corner piece is found. For the bevel this length of corner piece is taken on the blade, and the run *a b* on the tongue.

PROBLEM III.—*To find a circle equal in area to two or more other circles. See Figs. 175, 176, and 177 below.*

Let *A* and *B* be the two circles, with diameters of ¾″ and 1¼″ respectively; taking one measurement on the tongue and the other on the blade, the diagonal or cross measurement will give the diameter of the circle *C* equal to the other two. If a third circle had to be included, the diameter of the containing circle could be found by taking the diameter of the third circle on the tongue, and the resultant *C* on the blade, when the diagonal would once more give the diameter required.

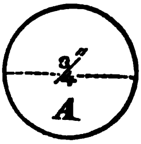


Fig. 175.

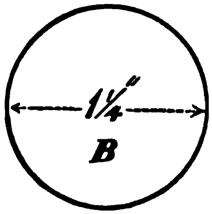


Fig. 176.

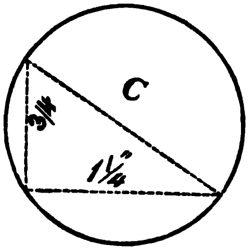


Fig. 177.

The same process is applicable to squares, and if care be taken to utilize similar dimensions only, triangles, hexagons, octagons, etc., may be also worked out; by similar dimensions being understood whichever side of a similar triangle may have been chosen, or the length of side or diameter of a polygon, whichever may have been taken. .

By the application of this rule it is possible to make one spout or pipe, whether square or circular, equal to a number of others.

PROBLEMS.

Problem IV.—*To find the center of a circle which will pass through three points, not in a straight line with each other.*

Taking *1*, *2* and *3* as the given points, draw straight lines between them, from *1* to *2* and from *2* to *3*. With the square, set off lines at right angles, from points half way between each pair of given points, as at *d* and *e*. The point of intersection of these perpendiculars is the centre of the desired circle.

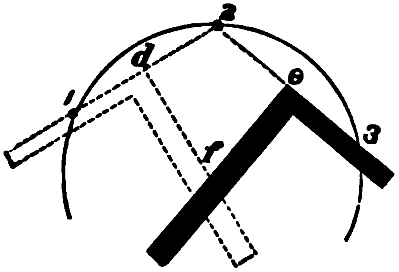


Fig. 178—Problem IV.

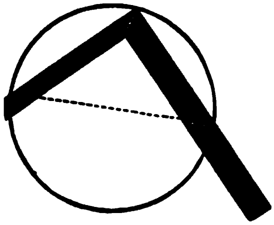


Fig. 179—Problem V.

Problem V.—*To find the center of a circle with the square.*

Lay the square on the circle with the outside corner just touching the circumference, mark the points where the blade and tongue cut the circumference on the outer edge. A line connecting these two points is always a diameter, and by drawing another similar line, the center of the circle is found at their point of intersection.

Note. *To test a large framing square* application is made of the proportions of 3, 4 and 5 to which reference has been made on pp. 47-49, in the section devoted to Staking Out. Two arcs or circles are described *from the same center* with radii of 12" and 16"; the compasses are next set to 20", and with one leg set anywhere on the outer arc, a point is marked off on the inner arc or circle *at the exact distance*. Next draw straight lines from these two points to the common centre, and an exact right angle is obtained for testing the square.

STEEL SQUARE PROBLEMS.

PROBLEM VI.—*To lay off an angle of 45°.*

The diagonal line connecting equal measurements on either arm of the square forms angles of 45° with the blade and tongue.

PROBLEM VII.—*To lay off angles of 60° and 30°.*

Mark off 15 inches along a line, as at *a b* (Fig. 180) and lay the square so that the blade touches one mark, and 7½" on the tongue is against the mark at the other extremity. The tongue will then form an angle of 60° with the line *a b* and the blade an angle of 30°.

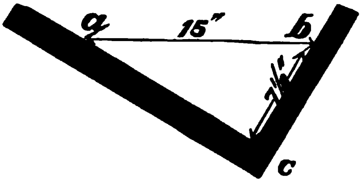


Fig. 180—Problem VII.

The same results can be attained by using other measurements one-half of each other, as 10" for *a b* and 5" for *b c*.

PROBLEM VIII.—*In a right-angled triangle, one side and the hypothenuse being given, to find the other side*, or *the base and perpendicular being given, to find the hypothenuse.*

This is equivalent to the process for finding out the proportions of braces.

For instance, let the given side be 2' 6", and the hypothenuse 5' 0", dividing these dimensions by four gives 15" for the hypothenuse *a b* as in Fig. 180, and 7½" for *b c* the side. On applying the square to the line, the length *a c* is found to be 13", which multiplied by four equals 52" or 1' 4" the required length of the third side.

To find the hypothenuse, it is simply necessary to take proportionate parts of base and perpendicular, as before, to lay off the diagonal between these proportionate parts as marked off on blade and tongue, and the multiplication of this diagonal by the number of proportionate parts taken, gives the hypothenuse.

PROBLEMS.

PROBLEM IX.—*The sides of a rectangular beam being given, to find the length of its diagonal.*

Take one-half, one-third or other proportionate part of one side upon the blade of the square, and the similar proportionate part of the other side upon the tongue; then the length along the line between the two marks is similarly proportionate to the diagonal, and being multiplied by two, three, etc., gives the length of the diagonal.

PROBLEM X.—*To find the side of a square equal to half the area of a given square.*

Taking *G* as the square; half its diagonal will give the side of a square equal to one-half its area.

By taking the *whole* of the diagonal of *G* as a side, a square would be constructed, *twice* the area of *G*.

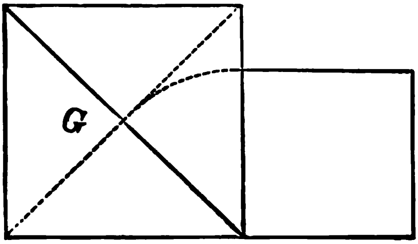


Fig. 181—Problem X.

PROBLEM XI.—*To lay off an octagon within a given square.*

This is the same as marking off an octagon on the end of a square log which it is desired to reduce.

Mark off the diagonal lines *e* and *f*, lay the square on each line in succession, marking off a distance from the centre equal to *half the width* of the square. One line being drawn, the square should be turned over as in the illustration Fig. 182 and by this means each corner will be marked off in turn.

Another method, as exemplified in Fig. 183, is to mark off a distance equal to the *side of the square* upon the diagonal *k;* the square should be laid upon the mark so found, and a line drawn to *o* as in the illustration. The distance *o n* is then scrieved off with the scratch gauge from each corner of the timber, as it represents the amount to be dressed off to form the Octagon.

PROBLEM XII.—*To lay off an octagon on a given side* (Fig 184).

Let *a b* be the given side on which it is desired to describe an octagon. Prolong *a b* and from this line lay off angles of 45° at *a* and *b* as was shown in Prob. VI. The perpendicular lines *1* and *2* are erected from *a* and *b;* when laying off the angles from *a* and *b* the length of side is marked off equal to *a b*, and from the points so found the lines *3* and *4* are erected. By applying the square to each line in succession, and marking off distances equal in length to *a b*, the remaining sides are plotted.

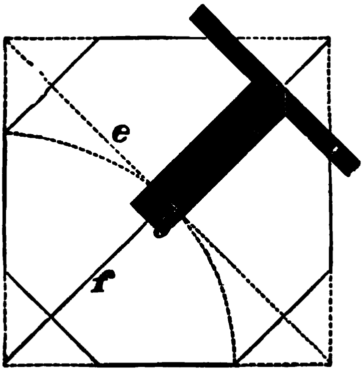


Fig. 182—Problem XI.

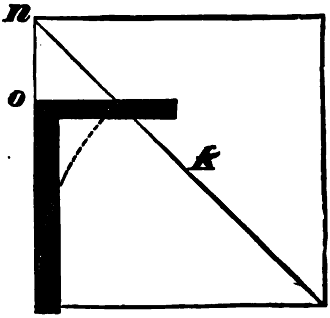


Fig. 183—Problem XI.

NOTE. The length of the side of a *hexagon* is equal to the radius of the circumscribing circle. If the side of a desired hexagon be given, arcs should be struck from each extremity of it at a radius equal to its length. The point where these arcs intersect is the centre of the circumscribing circle, and having described it, it is sufficient to prick off chords on its circumference, equal to the given side, to complete the hexagon.

PROBLEMS.

PROBLEM XIII.—*To find the side of an inscribed octagon when the side of the square is given.*

Multiply the side of the square by *five* and divide the product by *twelve;* the quotient is the side of the octagon. The answer is correct within one per cent.

PROBLEM XIV.—*When the side of the octagon is given, to find the width of the square necessary.*

Multiply the length of the octagonal side by 2.41 for accurate measurement, or multiply by 12 and divide by 5.

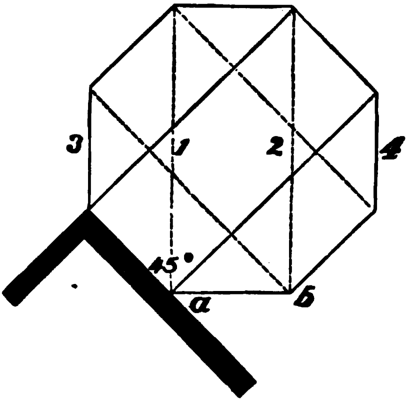


Fig. 184—Problem XII.

PROBLEM XV.—*To make a square stick octagonal.*

Near one end of the log place a square diagonally across it as shown in Fig. 185, so that the outside corners of the 24" blade touch the edges of the square stick. Make a mark at 7" and 17". Repeat the process at the other end, and draw lines through the pairs of marks, these lines showing what is necessary to come off the corners.

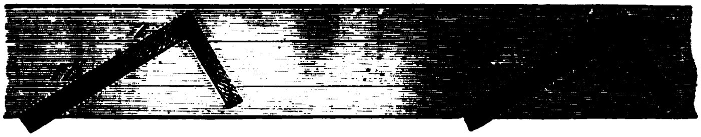


Fig. 185—Problem XV.

A two-foot rule can be utilized as well as the square for this purpose, but it is essential in each case that the corners of the rule or square just touch the corners of the stick.

STEEL SQUARE PROBLEMS.

PROBLEM XVI.—*To cut the best beam from a given log.*

Mark off the diameter *a c*, divide it into *three* equal parts *a 1*, *1-2*, *2 c*, and draw lines square with the diameter from *1* and *2* to *b* and *d*, lines drawn joining *a b c d*, mark out the largest possible beam.

If it be desired to cut out the *stiffest possible* beam, the diameter must be divided into *four* equal parts, and erecting perpendiculars as before, lines connecting their intersections with the circumference mark the outline of the desired beam.

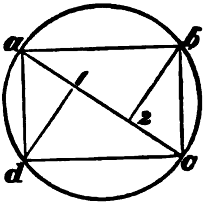


Fig. 186—Problem XVI.

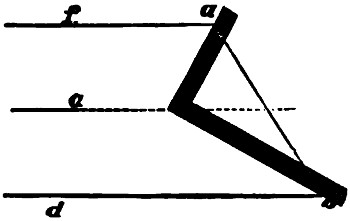


Fig. 187—Problem XVII.

The proportions of *a b* to *b c* are 1.414 to 1, and 1.732 to 1 in the two cases.

PROBLEM XVII.—*To bisect simultaneously two angles at the end of a brace.*

This is a problem often met with in mitering framing. Draw a centre line *c* parallel with the sides *f a* and *d b;* lay the corner of the square on this line *c*, with the outer edges of blade and tongue to the corners *b* and *a;* draw the bisecting lines along the edges of the square.

It will be clearly necessary that the sides *f* and *d* be parallel to use this method.

PROBLEMS.

Problem XVIII.—*To mark off the proper bevels in a truss.*

In Fig. 188, *a* is the straining beam, *b* the brace, and *t* the tie beam, the "run" of the brace being usually one-third the length of the tie beam, and the "rise" about one fourth.

First, finding the length and bevel of the brace from its rise and run, as with Prob. 1, the bevel of the lower end is marked on the stick, enough being added to compensate for what is cut out of the tie beam, to make the tenon joint.

Second, to lay off the bevel at the abutment of brace and straining beam, mark off the length of the brace or a proportional part along the edge of a board; take half the rise of the brace, or a similar proportional part on the tongue of the square, lay this measurement on one of the marks on the board, and move the square around until the blade touches the other mark;—a line drawn alongside the tongue gives the bevel for both brace and straining beam, the angle made by those two members having been bisected.

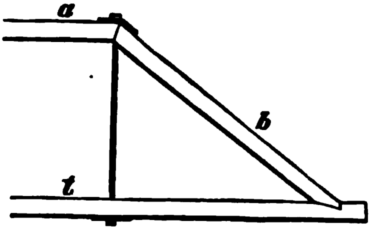


Fig. 188—Problem XVIII.

It is better to lay off the various measurements from the outside of the beam.

To bind the parts together, put in a tie-bar bolt as shown, with a plate washer, under the nut, bent to fit the angle made by straining beam and brace.

STEEL SQUARE PROBLEMS.

Problem XIX.—*To lay off the rafters of a hip roof.*

In Fig. 189 is shown a hip roof with two corners "out of square" or not forming right angles with the others. The timbers marked *a b*, *b c*, *e g*, *e g* are the *hip-rafters*, which form the corners of the roof, those running from eaves to ridge piece are *common rafters*, and the short pieces extending from hip-rafter to eaves are termed *jack-rafters;* the seats of each hip-rafter should form a square, as in the illustration, so that each one of a pair of jack-rafters as *J J* should be cut the same length.

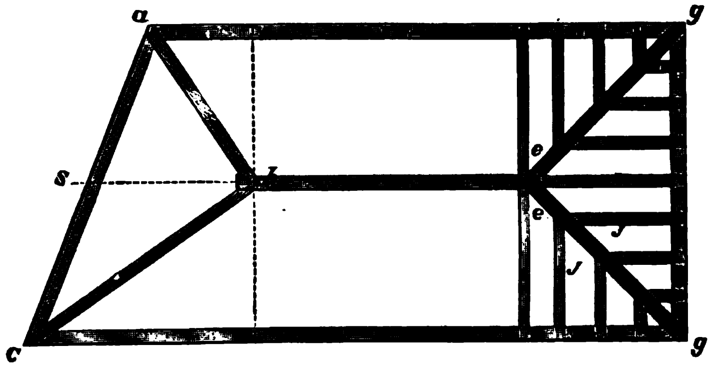


Fig. 189—Problem XIX.

For the sake of illustration, the roof is supposed to have a width of 16 feet, rise of 4 feet, length 30 feet on the shorter side and 35 feet on the longer.

In *laying off the hip-rafters*, it is better to consider first those upon the square end of the roof.

Take half the width of the building, or a proportional part, on each arm of the square, the diagonal will give the length of "seat" from *g* to *e*, measured along the *centres* of the rafters unto their *intersection* with the ridge piece. This length of seat taken as run with the rise of the roof will give the full length of the rafter, half the thickness of the ridge pole being taken square back from the upper bevel, to give correct measurement.

The upper bevel of a hip-rafter is termed the ***down bevel*** or ***plumb cut;*** it is always square with the ***lower-end bevel,*** and is therefore set off by the square by the same process as determines the length of the brace.

There is another method of finding these bevels, depending upon the fact that the diagonal of a 12″ square approximates very closely to 17″. Take 17″ on the blade, and the rise in inches per foot (the total rise in inches divided by half the width of the roof in feet), upon the tongue; then the blade will give the ***lower-end bevel,*** the tongue the down bevel. This is applicable when the hip-rafters are square with one another, the seats forming the diagonal of a square whose side is half the width of the building.

In the preceding cases it has been assumed that the hip-rafters abut the ridge piece at right angles, but, as shown by consideration of the plan, they meet at acute angles, forming what is known as the *side bevel.* If there were no slope to the roof, this would be half of a square or 45°, but with a pitched or sloped roof the hips always part from the right angle of the plan, and so the side bevels are always less than 45°. To lay off this side bevel, take the length of the hip or proportions on the blade of the square, and its run or proportions upon the tongue; the blade will give the proper cut for the bevel.

The backs of the hip-rafters must be beveled off so that they lie evenly with the planes of the surface of the roof, and this beveling must be from the middle towards either side. This is soon found by taking the length of the hip upon the blade, and the rise or pitch of the roof upon the tongue; this latter arm giving the bevel.

To lay out the jack-rafters; there are three in the plan between each corner and the first *common rafter*, making four spaces, or eight altogether across the end of the roof, which gives 2′ 0″ as the distance centre to centre of jacks. The rise of roof also divided by four, gives 1′ 0″ as the rise of the shortest *jack-rafter;* the run will also be 2′ 0″, as the hip-rafters form a square with each other.

Both rise and run .having been given the length, down and lower bevel are found as before, all measurements being taken from centre lines of the various rafters. The second jack-rafter will have twice, and the third three times the length, rise and run of the first.

The *side bevel* of a jack-rafter is found by taking the length of a common rafter on the blade and its run upon the tongue, the proper angle being obtained from the blade.

To lay out a roof which is out of square, it is necessary to apply Prob. XVII, which illustrates the mode of planning the seats of the hips. For length of these seats, take the distance from the intersection of the dotted line with the ridge piece to the corner upon the tongue, and half the width of the roof upon the blade. From the length of seat, thus obtained, taken upon one arm of the square, and the rise of roof upon the other, the full length of the hip-rafters is determined.

The side bevel of each rafter is obtained by adding together the full length of the rafter and its gain, or length of mitre, taking the sum of these measurements or a proportional, upon the blade and half the width of the roof upon the tongue, the latter showing the bevel.

The jack-rafters at the *side of the roof* are dimensioned for length and bevels by similar operations to those for the square end, the side bevel being found by taking the full length of a common rafter on the tongue of the square, and the distance from the dotted line near *b*, to the corner of roof as the measurement upon the blade; this latter marks off the proper cut.

For the *jack-rafters* on the *end which is out of square* it is necessary to give some consideration to their disposition. The old method of planning was to make the jack-rafter run truly lengthwise to the building, which made every one a different length and prevented pairing; the modern way is to set the jack-rafters at right angles to the end, and thus they will form pairs.

The spacing depends upon the length of the end, as there must be the same number of spaces, eight, as at the other end. One side of the roof being five feet longer than the other, 5′ 0″ is taken upon the tongue and 16′ 00″, the width of the roof, upon the blade, and the diagonal gives 16′ 9″ as length of the end from centre to centre of hip-rafters. Divide this by eight to get the centres of each jack-rafter.

To get the run of each rafter, measure the distance from the dotted line at *b*, where the hips intersect, to the middle of the end; this must be divided by four, or half the number of spaces, for the run of the shortest rafter, and by three and two for the others. The rise will be the same as for those at the square end.

STEEL SQUARE PROBLEMS.

For the side bevel of these jacks the length from *b* to *a* or *c* (depending upon which side of the middle) must be added to the gain of a common rafter running the same distance and taken as the blade measurement, and half the width of the roof upon the tongue; the line made by the former is the side bevel.

The foregoing rules give the full length of the various rafters, all dimensions having to be worked from *centre lines*, and therefore, whenever hip-rafters abut against a ridge piece, or jack-rafters against a hip, half the thickness of ridge piece or hip must be taken off, squared back from the down bevels of the various rafters.

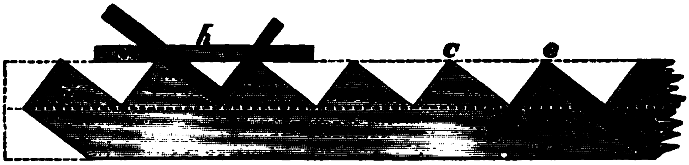


Fig. 190—Problem XX.

Problem XX.—*To mark out a flight of plain stairs.* The height from floor to floor must be carefully measured and the horizontal distance or run determined by means of the plumb-bob; the stringers or side pieces being measured for length and bevel the same way as the brace, marking off an inner line, *a b* in Fig. 190 as if the point required to be let into the post or beam.

A *whole number* without fractions is taken for the steps, and they are dimensioned as follows:—the tread varies from 9" to 12," the rise of each step from 6" to 8", the tread increasing as the rise increases; a good rule being tread multiplied by rise equals 66. The stairs should be 3′ 6" wide so that two persons can pass each other easily.

PROBLEMS.

Suppose the rise of the stairs to be 11′ 3″, which is equivalent to eighteen steps, each of 7½″ rise, and the run to equal 12′ 4″. This last measurement gives 8¾″ as the width of each tread, there being seventeen, or one less than the number of risers, the top floor serving as the last tread.

In marking off the steps, if the edge of the stringer is not planed, the square is applied to the chalk line *a b* as at *d* in Fig. 190, the tread being taken on one arm and the rise upon the other.

If the edge is dressed, the *fence*, as shown in Fig. 191, serves as a gauge. This is a piece of hard wood, sawn nearly through, edgewise, and which is clamped on the square by means of thumb-screws. This convenient appliance saves much time when numerous similar bevels, etc., have to be cut.

Fig. 191.

The *stair gauge* is a fence made of a steel angle bar. Each side measures ⅞″ wide, one leg being slotted to accommodate two sliding pieces. These work in the slots, are set to the desired points, and locked with thumb-screws.

Where it is impracticable to put a support under a flight of stairs, the triangular piece *c d e* should not be cut out, but, instead, a groove of the same shape with a depth of half an inch and a width equal to the thickness of the step. To assist in holding these, ⅝″ bolts should be run across, close under the tread, at each five feet of stair.

PROBLEM XXI.—*To lay off a spiral conveyor.*

Assuming the diameter of the central shaft to be 5″, and the pitch of the worm to be 7″, a stiff paper triangular template sim-

PROBLEMS.

ilar to Fig. 192, is cut out, the length of it equaling the circumference of the shaft, 5" x 3.1416 or 15.71", and the end of 7" corresponding to the pitch. The hypothenuse, or longer slant side, equals the length of each spiral.

Marking off a line parallel to the axis of the shaft, the 7" side is laid to it, and the pattern wrapped around, thus serving as a guide for marking off the course of the spiral, shifting along 7" for each further turn. By dividing the pitch into the length of the conveyor shaft, the total number of turns and consequent length of spiral is soon found.

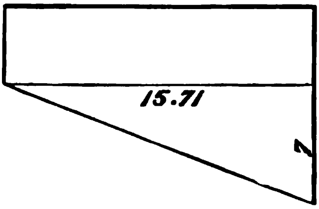


Fig. 192—Problem XXI.

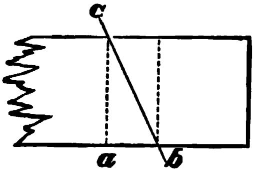


Fig. 193—Problem XXI.

Allowance will have to be made on one end of the pattern for the lap of the joints, and at its base for the flange by which it is fastened to the shaft.

Where the central shaft is octagonal instead of round, it is necessary to divide the pitch by the number of sides, giving $\frac{7}{8}''$ as the advance of the conveyor worm on each of the eight sides. In this case mark out a template as in Fig. 193, where *a c* represents the width of one side of the octagon on the blade of the square, and *b c* the fraction of the pitch upon the tongue. The hypothenuse will serve as a guide for transferring the spiral path of the conveyor to the shaft.

STEEL SQUARE AS A CALCULATING MACHINE.

By the application of a large bevel to the framing square, it becomes a *calculating machine*, and by its means arithmetical processes are greatly simplified. This bevel is preferably made of steel blades, procurable from a tool maker; the following points being observed in its construction:—the edges of each blade must be absolutely true; the blade *e* in Fig. 194 must lie *under* the square so as not to hide the graduations; the two blades must be fastened together by a thumb-screw to lock them; the blade *l* should have a hole near each end and one in the middle so that blade *e* may be shifted as required, with a large notch as shown, near each hole in order to observe the position of blade *e*.

Problem XXII.—*To find the diagonal of any square.*

Set the blade *e* to 10⅝″ on the tongue and 15″ on the blade, and screw the thumb-screw fast. Supposing that the square is 8″, the bevel is slid sidewise until the blade *e* is against the 8″ mark, when the other edge will touch $11\frac{5}{16}$″ on the blade of the square, which is the required diagonal.

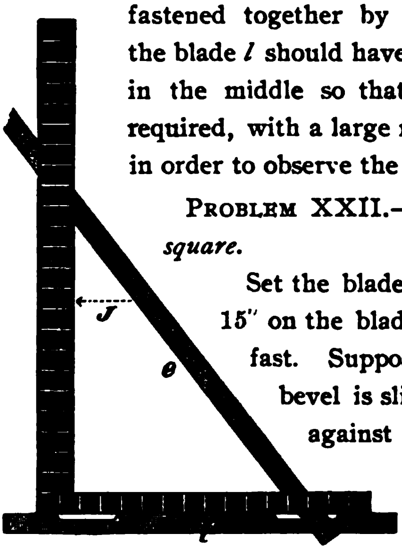


Fig. 194.

Problem XXIII.—*To find the circumference from the diameter of a circle.*

Set the bevel blade to 7″ on the tongue and 22″ on the blade of the square; the reading on the latter will be the circumference corresponding to the diameter to which *e* is set upon the tongue.

To reverse the process, use the same bevel, and read the required diameter from the tongue, the circumference being set on the blade.

STEEL SQUARE AS A CALCULATING MACHINE.

Problem XXIV.—*Given the diameter of a circle, to find the side of a square of equal area.*

Set the bevel blade 10⅝" on the tongue and 12" on the blade; the diameter of the circle, on the blade, will give the side of the equal square upon the tongue.

If the circumference be given instead of the diameter. set the bevel to 5½" on the tongue and 19½ on the blade, finding the side of the square on the tongue as before.

Problem XXV.—*Given the side of the square, to find the diameter of a circle of equal area.*

This, together with the preceding problem, is very useful in making calculations for spouts and pipes. Using the same bevel as in Prob. XXIV, the blade *e* is set to the given side upon the tongue of the square, the required diameter being read off the blade.

Problem XXVI.—*Given the diameter of the pitch circle of a gear-wheel, and the number of teeth, to find the pitch.*

Take the number of teeth or a proportional part upon the blade of the square, and the diameter or a similar proportional part upon the tongue, and set the bevel blade to those marks. Slide the bevel along to 3.14" on the blade, and the number given on the tongue, multiplied by the proportional divisor, will be the required pitch.

Problem XXVII.—*Given the pitch of teeth and diameter of pitch circle in a gear-wheel, to find the number of teeth.*

Set the bevel blade to the pitch on the tongue, and 3.14" on the blade of the square. Move the bevel along until it marks the diameter upon the tongue when the number of teeth can be read from the blade. If the diameter is too large for the tongue, divide it into proportional parts, also the pitch, multiplying the number found by the same figure.

Problem XXVIII.—*To use the bevel square as a scale rule.*

Set the bevel blade to 12" on the blade, and the number of inches to the foot on the tongue. Measure down the blade for the required measurement, *full size*, and a line at right angles, as *J*, Fig. 194, across the opening between the two blades, is the dimension reduced to scale

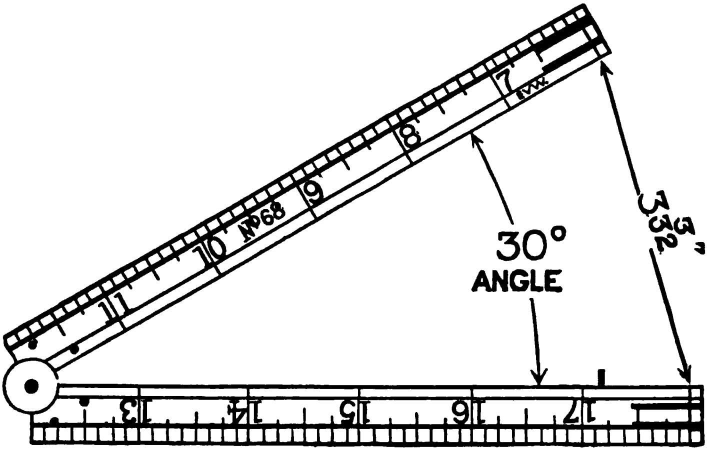


Fig. 195—Problem XXIX.

TABLE OF ANGLES ENCLOSED BY OPENING OF TWO-FOOT RULE.

OPENING.	ANGLE.	OPENING.	ANGLE.	OPENING.	ANGLE.
$\frac{11}{32}$ inch	5°	$3\frac{19}{32}$ inch	35°	$6\frac{7}{16}$ inch	65°
$1\frac{1}{32}$ "	10°	$4\frac{3}{32}$ "	40°	$6\frac{7}{8}$ "	70°
$1\frac{9}{32}$ "	15°	$4\frac{19}{32}$ "	45°	$7\frac{5}{16}$ "	75°
$2\frac{3}{32}$ "	20°	$5\frac{1}{16}$ "	50°	$7\frac{23}{32}$ "	80°
$2\frac{9}{32}$ "	25°	$5\frac{17}{32}$ "	55°	$8\frac{1}{8}$ "	85°
$3\frac{3}{32}$ "	30°	6 "	60°	$8\frac{1}{2}$ "	90°

LAYING OFF ANGLES.

Problem XXIX.—*To lay off an angle by means of the opening of a two-foot rule.*

Open the rule, as shown in Fig. 195, and measure the width of opening with another rule; by referring to the annexed table, the angle corresponding with any particular opening will be found. For instance, in the illustration, the jaws of the folded rule are open 3$\frac{3}{32}$″; on consulting the table the enclosed or *subtended* angle is found to be 30°.

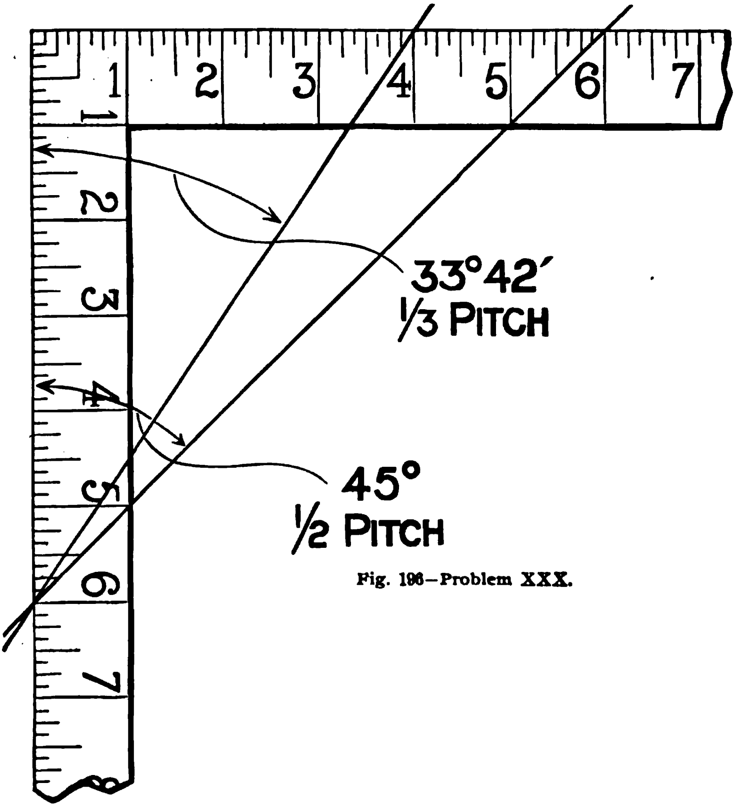


Fig. 196—Problem XXX.

PROBLEMS.

Problem XXX.—*To lay off any angle with the square.*

Mark off 6″ on the tongue, and the measurement found opposite the angle in the following table; the diagonal is the angle or mitre.

TABLE OF ANGLES FOR PITCH.

ANGLE.	BLADE.	ANGLE.	BLADE.	ANGLE.	BLADE.
5°	$\frac{17}{32}$ inches	26° 33′ ($\frac{1}{4}$ pitch)	3 inches	45° ($\frac{1}{2}$ pitch)	6 inches
10°	$1\frac{3}{64}$ "	30°	$3\frac{15}{32}$ "	50°	$7\frac{5}{32}$ "
15°	$1\frac{39}{64}$ "	33° 42′ ($\frac{1}{3}$ pitch)	4 "	53° 7′ ($\frac{2}{3}$ pitch)	8 "
18° 25′ ($\frac{1}{6}$ pitch)	2 "	35°	$4\frac{13}{64}$ "	55°	$8\frac{9}{16}$ "
20°	$2\frac{3}{16}$ "	40°	$5\frac{1}{32}$ "	60°	$10\frac{25}{64}$ "
25°	$2\frac{51}{64}$ "				

Problem XXXI.—*The side of a polygon having been given, to find the radius of a circumscribing circle.*

Taking the square with the bevel attachment as in Fig. 194, the bevel is set to the pairs of numbers in the following table, taking one-eighth or one-tenth of an inch as a unit. The bevel, when locked, is slid along to the given length of side, and the required length of radius is at once read upon the other leg of the square.

Thus, having to set out a pentagon with a side of six inches, the bevel is set to the figures in column 5, the lesser number on the tongue. In this case $\frac{74}{8}=9\frac{1}{4}$″ on the tongue, and $\frac{87}{8}=10\frac{7}{8}$″ on the blade. Sliding the bevel to 6″ upon the blade, the length of the radius, $5\frac{3}{32}$″ will be read upon the tongue.

TABLE FOR INSCRIBED POLYGONS.

Number of Sides	3	4	5	6	7	8	9	10	11	12
Radius	56	70	74	60	60	98	22	89	80	85
Side	97	99	87	60	52	75	15	95	45	44

SUBDIVISION OF CIRCLES.

PROBLEM XXXII.—*To divide the circumference of a circle into a given number of equal parts.*

From the column marked Y in the following table, take the number opposite the given number of parts. Multiply it into the radius of the circle; the product will be the length of chord to set off upon the circumference.

PROBLEM XXXIII.—*Given the length of a chord, to find the radius of the circle.*

This has already been stated for use with the steel square and bevel attachment, in Problem XXXI., but the present form may be found more expeditious for calculations. The method is useful for ascertaining the diameter of gear-wheels, the pitch and number of teeth having been given.

Multiply the length of the chord, width of side, or pitch of tooth by the figures found corresponding to the number of parts in column Z of the following table. The result is the radius of the desired circle.

TABLE OF CHORDS OR EQUAL PARTS.

No. of Parts		Y	Z	No. of Parts	Y	Z	No. of Parts	Y	Z
3	Triangle	1.732	.5778	15	4158	2.4050	40	.1569	6.3728
4	Square	1.414	.7071	16	.3902	2.5628	45	.1395	7.1678
5	Pentagon	1.175	.8006	17	.3675	2.7210	50	.1256	7.9618
6	Hexagon	1.000	1.0000	18	.3473	2.8793	54	.1163	8.5984
7	Heptagon	.8677	1.1520	19	.3292	3.0376	60	.1047	9 5530
8	Octagon	.7653	1.3065	20	.3129	3.1962	72	.0872	11.468
9	Nonagon	.6840	1.4619	22	.2846	3.5137	80	.0785	12.738
10	Decagon	.6180	1.6184	24	.2610	3.8307	90	.0698	14.327
11	Undecagon	.5634	1.7747	25	.2506	3.9904	100	.0628	15.923
12	Duodecagon	.5176	1.9319	27	.2322	4.3066	108	.0582	17 182
13		.4782	2.1911	30	.2090	4 7834	120	.0523	19.101
14		.4451	2.2242	36	.1743	5 7368	150	.0419	23.868

STRUCTURES.

In natural order the subject of buildings or structures follows the preceding pages which have been devoted to those relating to excavations and foundations.

Building is the art of construction applied to a variety of objects as houses, bridges, wharves, ships, &c. The term architecture, of which building is the mechanical execution, is in common use limited to the construction of buildings for the purposes of civil life. Building also is commonly understood to apply to only the first class of objects, unless otherwise specifically designated.

One of the primary meanings of the term *structural-mechanics* implies an arrangement of parts or manner of building or erecting, hence the use of the word *structural;* the word *mechanics* includes the action of forces on all bodies, whether solid, liquid, or gaseous. It is sometimes, however, and formerly very often, used distinctively of solid bodies only.

The consideration of the scientific principles involved in building mainly depends upon the laws governing the strength of materials, and composition and resolution of forces. To calculate the strength of the combinations resort must be had to *the parallelogram of forces*, by the aid of which the resultant pressure is readily determined in any system of framing however complicated.

An important rule to be observed is, *that stiffness or rigidity of form in any framework is of greater consequence than the comparative strength, since* any modification of the latter can always be secured by varying the strength of the different parts.

One great doctrine of physics expressed in Latin is this, *Ex nihil, nihil fit*—From nothing, nothing is made. This means that we can never observe any creation out of nothing. This we owe to the period of Thales, who was born 686 years before Christ.

STRUCTURES.

The triangle being the only figure, the form of which cannot be changed except by altering the proportions of its sides, it is evident that the rigidity of framework can be best secured by the adoption of a triangular system—that is, by dividing the entire framework into a system of triangles, by means of *ties and struts*. The latter are the pieces employed to resist the effects of compression; the former, those of extension. This distinction must be closely observed in planning any system of framework, as a confusion in this respect might prove destructive to the entire work. In all designs for framing, this principle is to be borne in mind—that the strength of the weakest point is assumed as the strength of the entire system.

Generally speaking, the practical builder should be familiar with *Brick*, *Stone*, *Timber*, *Beams*, *Lime*, *&c.*; and also the various minor portions or processes of construction, as *Foundations*, *Carpentry*, *Painting*, *Warming*, *Ventilation*, *&c.*

The materials of building are received by the millwright or carpenter in the form of *Beams*, *Scantlings*, *Planks and Boards*. The names of different parts of framing will be found in the note below.

The millwright's labors are limited mainly to the skeleton of the structure,—to those portions which are indispensable to its stability and efficiency. The operations he performs are principally scarfing, notching, cogging, trimming, pinning and wedging.

Floor beams are called *joist pieces;* those supporting the roof are called *rafters;* and uprights in wooden walls or partitions, *studdings* or *studs*. Beams which support the floor joists between the walls or partitions are called *girders*. Similar beams under the rafters of a pitch roof are called *purlines*. Small timbers, such as 2x4 inches, 2x6 inches, or 8x4 and 4x4 inches, are called *scantlings*. Pieces measuring 4x6, or over, are called *timbers*.

SCARFING.

Scarfing is a mode of connecting beams horizontally, and is performed by cutting away part of the substance of each beam for a certain length, bringing the cut portions together and fastening them by screws, bolts, straps or wedges. Where strength only is required without regard to appearance, beams may be lengthened by "fishing," instead of scarfing. In this, the beams are brought end to end, and lapped on opposite sides with short pieces of strong plank, which are secured by bolts which pass through both pieces and the beam between them. If bolts and straps are well applied, this form of joint is as well adapted to resist transverse as longitudinal strains. This form is shown in Fig. 197 where to reduce the strain upon the bolts the beam is indented or tabled on the upper side and joggles or keys are inserted. In designing scarfs, the kind of strain to which the piece is to be subjected, whether longitudinal, transverse or a combination of both, is to be particularly considered. In the

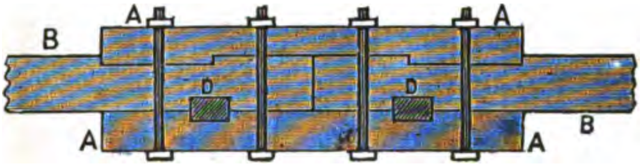


Fig. 197.

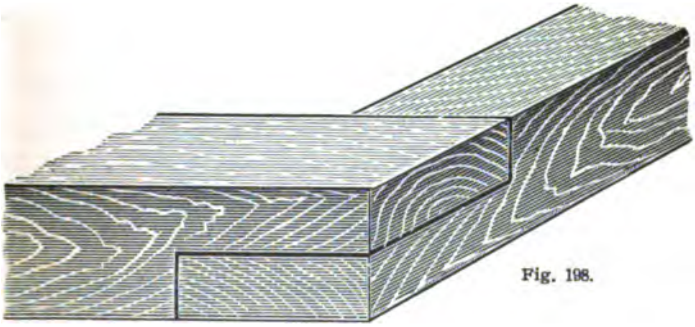
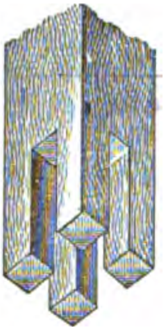


Fig. 198.

SCARFING.

ordinary form no provision is made for resisting longitudinal strains, except so far as the bolts may answer this purpose, and also the adhesion or friction of the two beams. More elaborate methods of jointing are therefore devised, in which the resistance of wood to splitting is employed to secure the pieces which are drawn together by the aid of keys or double wedges. Bolts and straps may also be used to impart additional security.



In *scarfing bond and wall plates*, it is usual to cut about ⅜ through each piece on the upper face of the one, and the under face of the other, about 6 or 8 inches from the end, transversely, forming what is termed a kerf, and longitudinally from the end from ⅜ down on the same side, so that the two pieces lap together like a half dove-tail. These joints are generally spiked, and it is *always* required that they shall fall in or under a pier, although the supervening weight of the wall and joists render it impossible to draw them apart, except by tearing the fibres asunder or lifting the weight. Fig. 198 illustrates this joint.

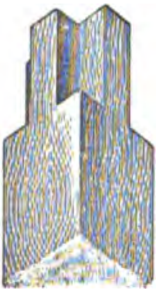


Fig. 199.

Longitudinal joints are employed when the only pressure to be sustained is a vertical one. They are made quite short, as they are designed only to keep the two pieces in the same line. A common mode of making these joints is to divide the end of each piece into 9 squares; then 5 of these being cut away in one piece and the 4 alternate squares on the other, the two beams exactly fit each other. This is illustrated in Fig. 199.

NOTCHING AND COGGING.

In scarfing no joint should be used in which shrinkage or expansion can tend to tear away the timber, and it may be said that—

No joint can be made as strong as the timber itself.

Notching is of two kinds, square and dove-tailed and is used in connecting the ends of wall plates and bond timbers at the angles, in letting joists down on beams and binders, purlines, principal rafters and the like.

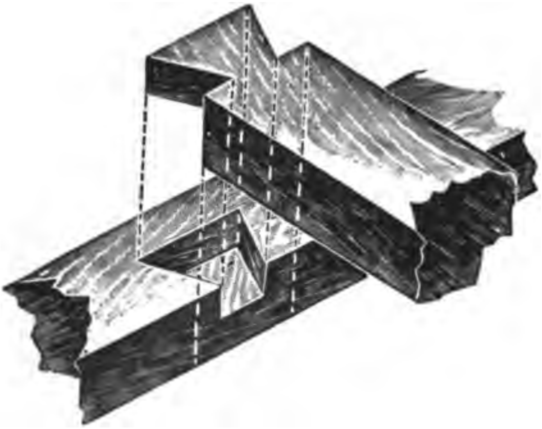


Fig. 200.

Cogging is a species of notching used principally in connecting the beams to wall plates, a shallow notch of the width of the wall plate being cut out of the under side of the beam, and a similar notch cut on the wall plate to receive the beam. The two notches fitting closely, all motion either side or endwise is prevented.

Fig. 69 on page 94 of this book is a good example of *cogging*, being used in this instance to connect a joist with a sill. The foundation supports nearly two thirds of the joist, and the whole makes a cheap yet substantial job. Where larger sills are used, a different form of joint is employed, which will be described later.

Flooring joists are often connected with trimmers or main joists in the same general manner, except that dovetailed notches are employed instead of square. As there is seldom any great amount of force tending to detach the joists from the trimmers, this form of notch may be amply sufficient. As a rule dovetail joints should not be employed in millwrighting when the grain of one piece of wood crosses that of the other, for the shrinkage of timber is much greater across the grain than in the direction of its length; hence dovetails are apt to wear loose after a time, and throw the entire strain upon the pins or bolts, which were originally employed only to assist the joint.

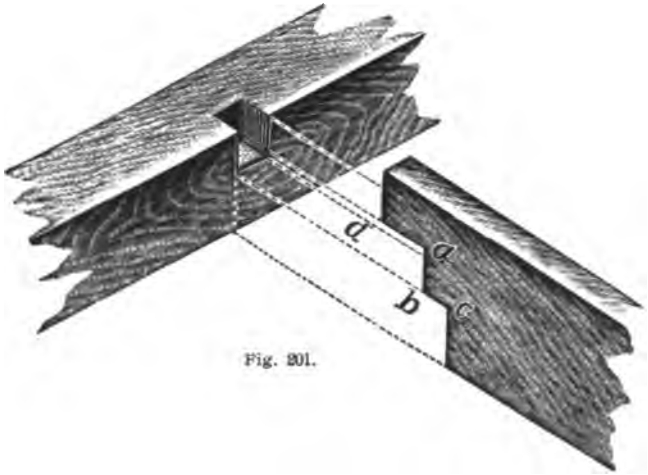


Fig. 201.

TENONING.

When the grain runs in the same direction dovetails can be employed with advantage, since the shrinkage of one piece is counterbalanced by the contraction of the other, which allows the joint to remain firm. Such cases, however, are met with more frequently by the joiner than by the millwright. An example of both cogging and dovetailed notching is shown in Fig. 200, where they are employed to fasten a beam to a wall plate.

Tenoning implies mortising also, both being required to connect two pieces by means of a small projection on one, termed a tenon, and a corresponding cavity on the other, called a mortise. *Tenons and mortises must exactly correspond in size.* They are generally placed at equal distances from one or the other side or edge of the two beams to be connected; usually, too, all angles formed in the process of tenoning, whether internal or external, are right angles.

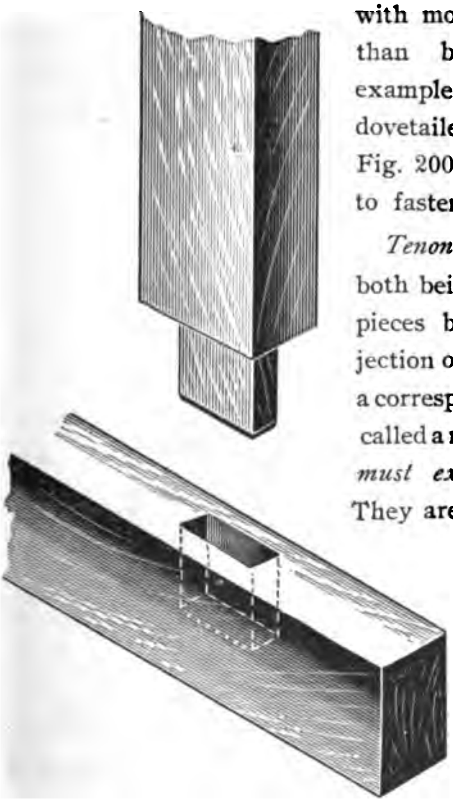


Fig. 202.

A combination of tenoning and cogging is shown in Fig. 201, illustrating what is known as a *gained joint*, much used for connecting joists or floor beams to sills or girts. The tenon proper is the corner *a b c* which fits into a corresponding recess in the

TENONING.

sill. Thus the total length of bearing surface *d a* and *b c* is equal to the width of the beam, and yet the floor joist is firmly held in the recess, without appreciable weakening of either part of the framing. This makes a very effective joint to resist bending or shearing stresses.

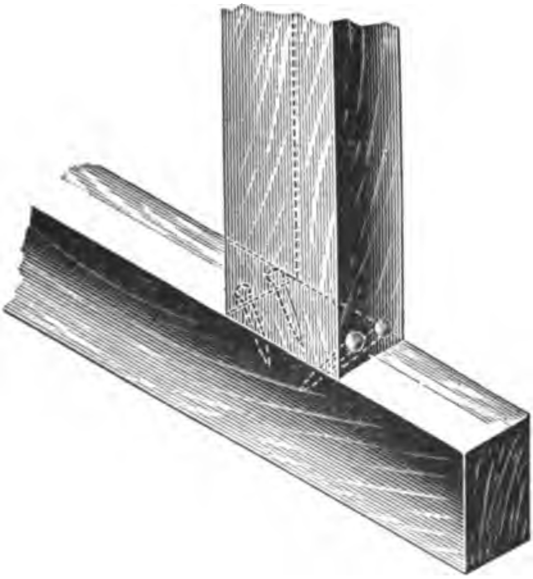


Fig. 203.

The ordinary *tenon* is shown in Fig. 202, together with its *mortise*. The latter is made by first boring suitable holes, and then removing the wood with the chisel, half from each side.

In Fig. 203 will be found an expedient termed *toe nailing*, which is resorted to where a post abuts upon a sill and cutting of either is impracticable or undesirable. As will be seen, four strong spikes replace the tenon.

JOGGLES.

Very short tenons, termed *joggles*, are sometimes used for preventing lateral motion in two pieces of timber, as at the connections of a king or queen post with the principal rafters, or with the struts. With the same view, the ends of *king* and *queen posts* are generally tenoned into the tie-beams, and the feet of the principal rafters of a roof are also tenoned into the tie-beam.

The pressure in this case being very oblique to the surface of the tie-beam, it is usual to employ bolts and nuts, or, what is better, stirrup irons or straps.

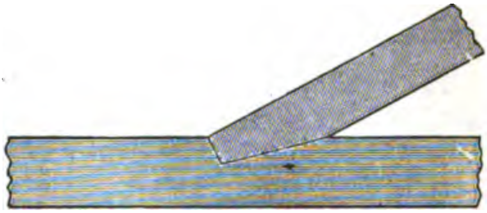


Fig. 204.

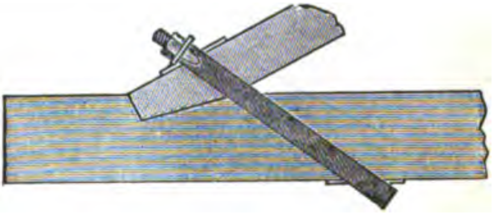


Fig. 205.

A simple joggle as employed in uniting the *principal* rafter of a roof with its tie-beam is shown in Fig. 204. The method of reinforcing such joints with straps and plates is well shown in Fig. 205; the *heel strap* itself, illustrated in Fig. 206, should not be less than 1⅛″ x ¼″ to avoid cutting into the fibres of the wood.

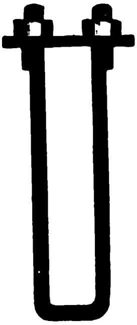


Fig. 206.

In forming mortises and tenons, the latter should be made as large and efficient as practicable, with due reference to maintaining the proper degree of strength of the other piece, which by too large a mortise might be materially weakened. To avoid

TUSK TENONING.

the danger of too great a mortise and too small a tenon, and also of lessening the efficiency of either of the two pieces, in consequence of the tenon being placed too high or too low, it is customary to employ a compound called a *tusk-tenon* for most horizontal bearings of importance, as to joists and binders, to trimmers, beams, girders, &c.

The body of such a tenon is a little above the middle of the end, and runs out from two to four inches, as may be required.

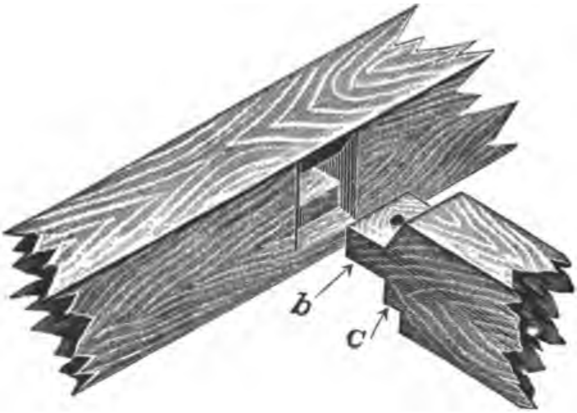


Fig. 207.

Below it protrudes the tusk and above it the shoulder is cut down at an obtuse angle with the horizontal line, thus giving to the tenon the strength of the whole depth of the timber above the under tusk, and giving it a bearing in a shallow mortise, while a greater depth of the mortised piece than that which the tusk rests on receives the body of the tenon, thus protecting its comparatively narrow margin from under-pressure.

This tenon is illustrated in Fig. 207, where *b* is the small *tenon* and the angle beneath it constitutes the *tusk.* This makes a very

PINNING AND WEDGING.

satisfactory joint much favored by millwrights, and is especially applicable where the connected members have to be flush with each other.

Pinning and wedging are resorted to when tenons have to resist not only lateral displacement, but strains tending to draw them from their mortises.

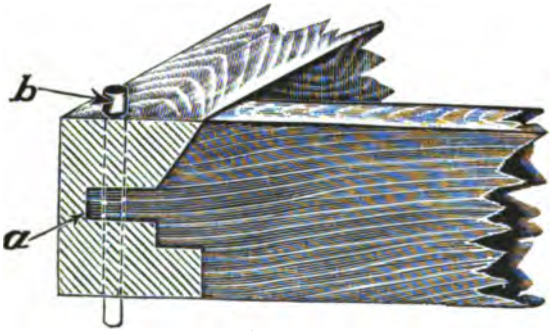


Fig. 208.

In pinning, an oak pin or tree-nail, or an iron bolt is driven through both the tenon and the sides of the mortise as seen in Fig. 208, where *b* is the pin or dowel driven through the sill, locking the tenon *a*. The tenon may also be prolonged through the sill or beam, when the fastening becomes that shown in Fig. 209, where the square pin *b* is inserted beyond the thickness of

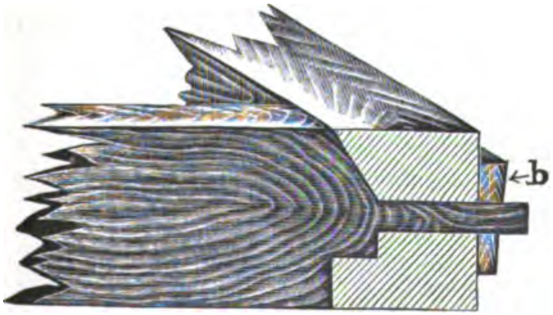


Fig. 209.

PINNING AND WEDGING.

the mortised piece. For substantial framings which may have to be dismounted for transport, this makes an ideal joint.

Wedging is the insertion of triangular pieces into or beside the end of a tenon, so that the mortise, which is frequently made to taper outwardly for that purpose, may be more completely filled, binding the tenon.

The practice is usual in scarfing, cogging, and notching to cut in the shoulder with the saw, and to strike out the cheek with the mallet and chisel, or with the adze. Tenons are made entirely with the saw. Mortises are usually formed by boring at the ends with an auger, the diameter of which is equal to their width, and striking out the intervening portions with a chisel, applying this in the direction of the grain of the wood. The ends are squared with a chisel just as broad as the width of the mortise.

Pins or tree-nails of wood must be split, not sawn, to insure their tenacity, and wedges must be cut with the saw. For these uses straight-grained stuff is to be preferred. The bearing surfaces of framing and bearing joints should be as large as possible, and, when practicable, cut at right angles with the direction of the pressure, or (when one piece bears longitudinally upon another) in a circular arc, so that the pressure may be distributed equally over the bearing surface.

Shoring or propping up the walls or floors of a building is also performed by the millwright or carpenter, while pugging or deafening floors, furring down joists, and bracketing and cradling for plastering, etc., may be performed either by the carpenter or joiner, as less or greater precision is required.

FRAMING.

A combination of joints used in the framing of a building is seen in Fig. 210. It will be noticed that the *end girt* (to the right) is of the same scantling and at the same level as the floor joists, being mortised into the *post* or vertical member. The side girt, generally termed *drop girt*, as it is placed below the level of the flooring, is generally a substantial timber and connected with the post by means of a splayed bevel joint so arranged that a bearing equal to about $\frac{1}{3}$ the thickness of the post is secured. It is customary to make this type of joint with a tenon, fitting into a mortise in the post, the whole being pinned together.

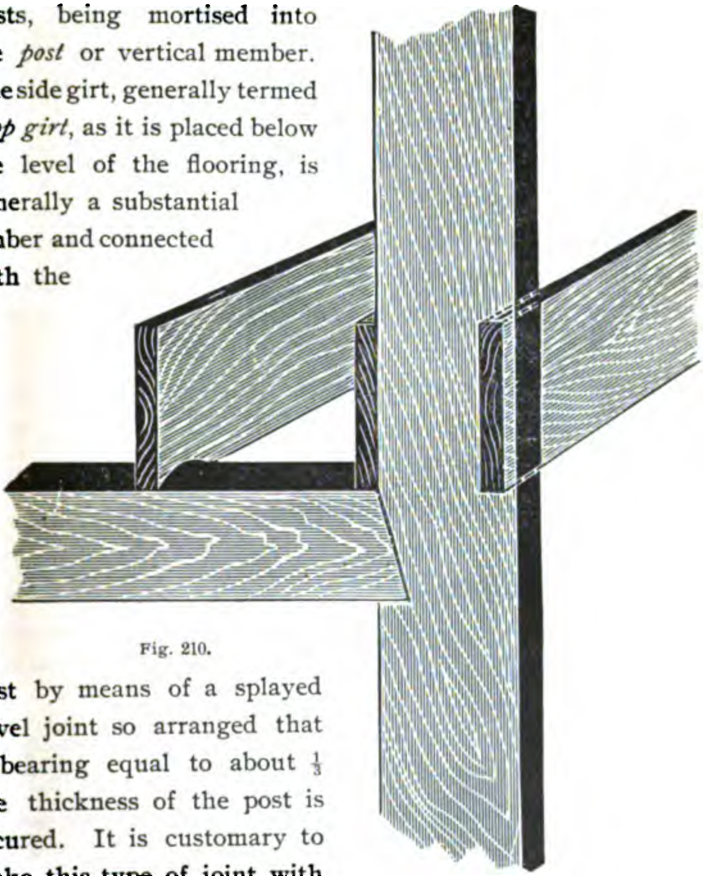


Fig. 210.

FRAMING.

This splayed bevel joint is recommended for the insertion of flooring joists into a brick wall, of course without a tenon; a bearing length of four or five inches being provided. The end of the joist should never be squared, as the arrangement is designed, in case of fire, to permit the joist to drop and pull out without damaging the wall. As the joist is usually fixed by the addition of an anchor set in the brick-work, it is advisable to secure the primary reason for this joint by placing the anchor as low down on the bevel as possible.

In order to provide timber foundations which may be easily taken down for transportation, the millwright has recourse to combinations of notching and wedging, as seen on page 205. Fig. 227 has a rabbet along one edge of the cross-beam, the wedge filling the other dovetail of the sill, and having a good vertical bearing surface. Fig. 228 costs more to make, with dovetails each side of the beam, but is a more secure fastening.

In dealing with roof and bridge trusses, also with the framing for standards supporting shafting, millwork, etc., it is necessary to joint heavy timbers to each other at a less angle than a right angle. The simplest method of effecting this has been already shown in Figs. 204-205, where the simple joggle or *stub-tenon* was illustrated.

The same result is achieved with less weakening of the tie-beam or horizontal member by means of the *bridge joint* shown in Figs. 211-212. The former is similar to the square mortise and tenon, but is cut in a different manner. The tenon *a*, on the inclined piece, is cut with its outer edge (near the letter) nearly vertical, while its inner edge is parallel to the side of the piece; the horizontal piece being mortised to correspond for its reception. The *straddle joint* illustrated in Fig. 212 is a direct reversal of the other bridge joint, the tenon *b* being cut in the tie-beam, the inclined piece or *principal* being mortised as at *a*. With this second joint the principal has the advantage of being well joggled into the tie-beam, and there is less need of heel straps or side irons.

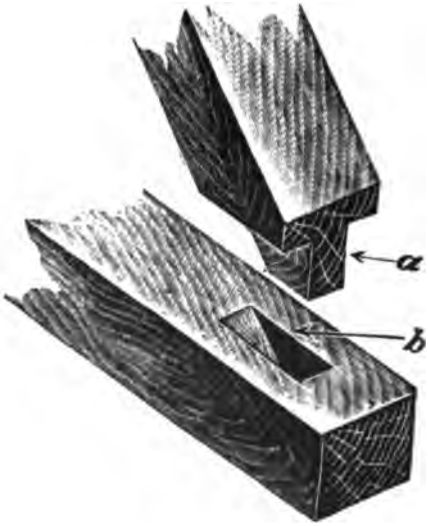


Fig. 211.

The method of setting out the angles, etc., for a roof or bridge truss has been dealt with in the section dealing with the steel square.

The illustrations on page 198 show three designs for timber bridges of short span. Fig. 213 is a simple truss of small size for a span of about 20 feet, with a pitch of one-third the span, or a rise of eight inches for each running foot. Fig. 214 is slightly

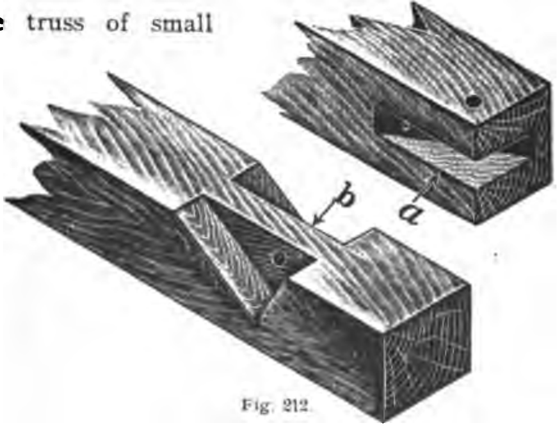


Fig. 212.

BRIDGE TRUSSES.

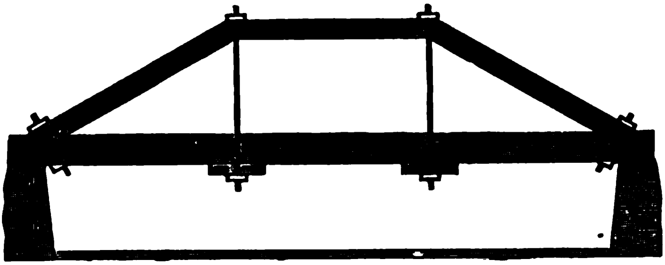


Fig. 213.

more elaborate, being designed for a span of 30 or more feet, and a pitch of one-fourth, equalling a rise of six inches to the foot.

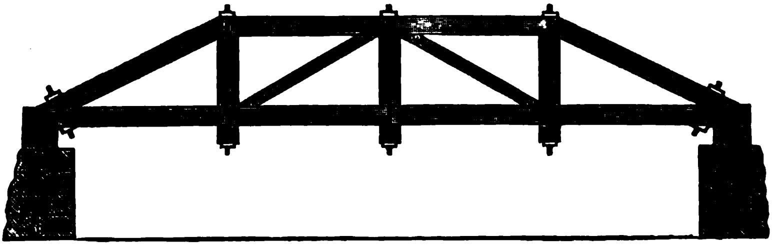


Fig. 214.

This truss has good struts to relieve the compressive strains of the structure.

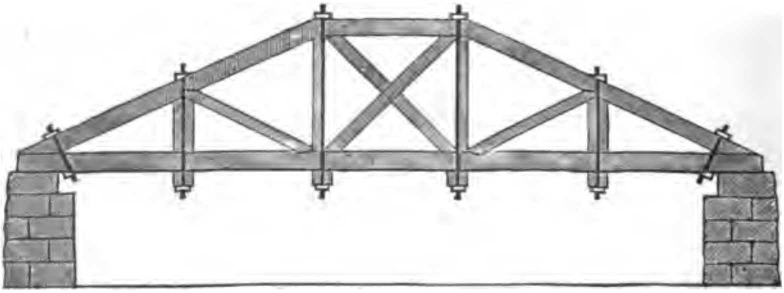


Fig. 215.

KING-POST ROOF.

A good substantial bridge for spans of forty to fifty feet may be made like Fig. 215, each bay being made eight to ten feet long as the case may be. Should it be necessary, the same span can be increased to sixty feet by making the central bay double, as in Fig. 214. See note below.

A good roof of the *king-post* variety is illustrated in Fig. 216, which is sufficiently clear to be self-explanatory.

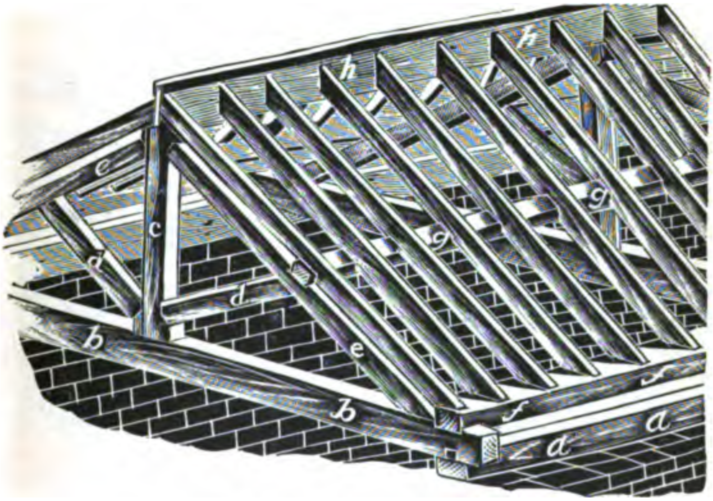


Fig. 216.

The wall plates are marked *a a*, the tie-beams *b b*, *c* is the king-post and *d d* the struts. The principals are marked *e e*, and the

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NOTE.—Recommended scantlings are:—Tie-beams 15" x 20"; braces or principals and the top rail or straining piece 12" x 15"; struts and stiffness 8" x 12"; wall sills and the floor beams under each bay 15" x 18". The floor joists should be 4" x 10", spaced 8' 0" centres, with decking of 8" x 9". The iron bolts should be 1½" diameter with a plus thread, that is, the ends of the bolts jumped up or enlarged so that the diameter at the bottom of the thread is equal to that of the body of the bolt. In this case the screwed ends will be 1¾" diameter unless a pipe thread is chosen. The short bolts may be 1¼" diameter.

purlins *g*. The letter *h* designates the ridge piece, and the pole plates upon which abut the other ends of the common rafters are denoted by *f f*.

Where two upright posts are used, dividing the span into three equal bays, they are termed *queen-posts*, the arrangement of the truss being not unlike the bridge shown in Fig. 213, of course with the arrangement of struts and braces shown in Fig. 214.

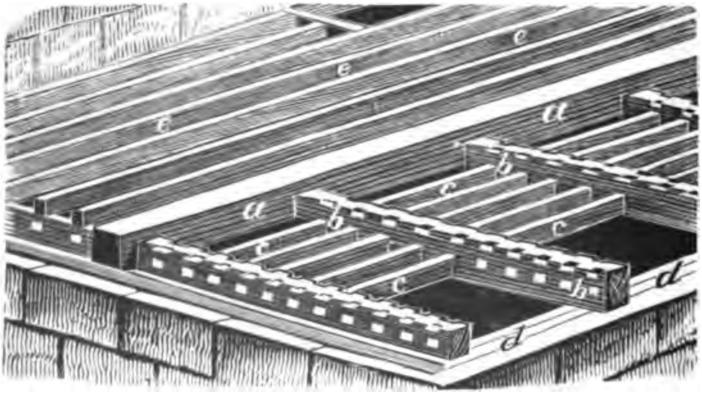


Fig. 217.

Fig. 217 shows the timbering of a floor, which also is the ceiling of the room underneath. *A a* is the *girder* or *bressummer*, *b b* the *binding joists*, also known as *trimmers*, *c c* are the *ceiling joists*, *d d* the wall plates, and *e e* the *bridging joists*. The nomenclature is sometimes varied; the floor joists as *e e*, running the length of the building, are termed *headers*, transverse joists as seen near the opening in the upper part of the illustration being known as *trimmers*, while the notched lateral timbers *b b* are in that case called *bridging*.

DEFECTS IN TIMBER.

In laying a floor it is necessary to put the planking or decking *with the heart-wood down* as shown in Fig. 218, care being also taken to put the nails on each side, as seen in the illustration. Nails in the centre of a board tend to cause it to warp.

When planks are laid in the reverse manner, as in Fig. 219, the wood wears unevenly, and the layers of wood fibres tend to curl up at the ends, where the grain terminates in a point.

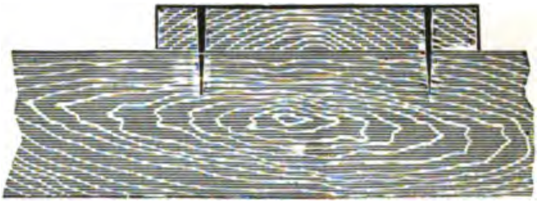


Fig. 218.

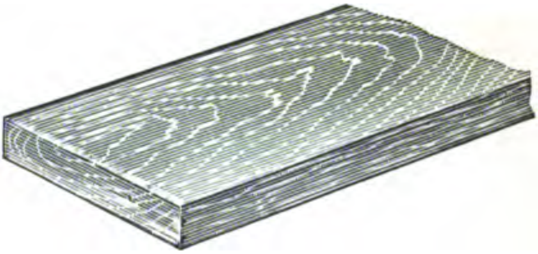


Fig. 219.

In dealing with timbers, defects due to the growth of the wood, or to the processes of seasoning and drying, will be met with. To understand them properly some knowledge of the nature of the tree itself is desirable.

Heart-shakes, as seen in Fig. 220, occur in the centre of the tree, and are common to all kinds of timber. *Star-shakes*, as in Fig. 221, are simply a further development of heart-shakes, and neither are particularly harmful unless large. *Cup-shakes*, similar to Fig. 222, separate one layer or ring from the next, and are supposed to be caused by wrenching of the fibres during severe wind storms. This defect is more serious, and is especially predominant in

DEFECTS IN TIMBER.

timber sawn from the hemlock tribe. Recent authorities are inclined to attribute both heart and cup-shakes to internal stresses set up by the expansion of the sap-wood.

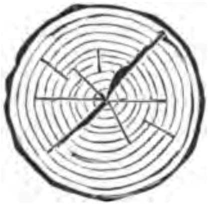


Fig. 220.

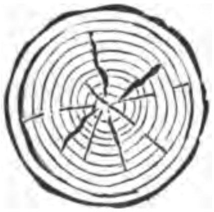


Fig. 221.

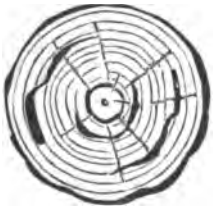


Fig. 222.

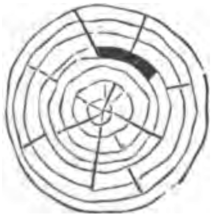


Fig. 223.

Rindgalls, illustrated in Fig. 223, are dead portions of the outer rings, occasioned by some injury to the tree. Subsequent growth has encased them within the more recently deposited layers of fibre.

Knots are the basal portion or root of a limb which has lived, and broken off, being then covered by the growth of fresh annual rings. In pine and other cone-bearing trees these dead knots are generally loose, and fall out when the timber is sawn.

The lateral bending of the bundles of fibres, to form the branch or limb, also constitutes knots, and, as the fibres above such branching are usually separate, it will be found comparatively easy to cleave both stem and knot from underneath the branch. The axe will turn aside from the knot when splitting from the upper side, in consequence of the before-mentioned separation of fibre.

The foregoing defects are formed in the living tree, while *wind cracks*, illustrated in Fig. 224, convey the usual appearance of *checking*. This takes place in seasoning, when the moisture dries out of the vessels and ducts in the wood; the walls of the cells contracting and their area shrinking, while the height remains practically unchanged.

The unequal contraction of neighboring cells of varying sizes causes the distortion of timber known as *warping*.

Much of this is owing to the outer cells drying while the interior is yet full of moisture, such a state being known as *case-harden-*

NOTE.—The timber trees growing in temperate climates are termed *exogens*, which means that they grow from the centre outwards by the accretion of fresh circumferential rings each year. The other great family of *endogens*, in which the new fibres are interspersed among the old, have an appearance similar to the familiar cane, and, in tree form, at least, are more generally tropical. The exogenous trees consist of bundles of cellular fibres lying parallel with the axis of the stem, together with other fibres known as *medullary rays*, radiating from the centre to the bark, which serve to bind the whole together. In cone-bearing trees, like the pines, there are numerous resin ducts, while the broad-leaved trees have other hollow cells or vessels.

In spring time the roots absorb moisture and various substances from the soil, which is converted into sap or juice, and rises through the cellular fibres to form leaves. The leaves act as lungs, by the action of sunlight on their chlorophyll or green coloring matter, giving off moisture and absorbing carbous dioxide from the atmosphere, the sap becoming consequently denser. After a period of suspended vegetation the sap descends, during autumn, chiefly between the wood and the bark, depositing the annual ring of new growth, covering all parts of the trunk and branches. The wood deposited in the upward course of the sap is termed *spring wood*, and is much lighter in color than the *summer wood* which is deposited as the sap descends, the latter being also stronger and denser. The greater the proportion of summer wood, the stronger the tree. As the tree gets older the central layers become choked with its characteristic secretions and so serve only the purely mechanical function of supporting the tree; thus are developed the two kinds of wood known as *sap-wood* and *heart-wood*. The *shrinking* and *checking* of the timber is affected by the greater or less predominance of sap-wood, and also by the medullary rays.

ing, and is a frequent accompaniment of kiln drying. To minimize it, steam is sprayed into the kiln so that the exterior shall keep moist while the interior is drying.

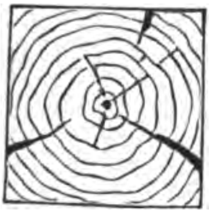


Fig. 224.

Fig. 225 shows *sappy corners* in a dressed log, caused by shrinking of the sap-wood. *Waney edges*, as in Fig. 226, show similar shrinkage at the ends of a board from the same cause.

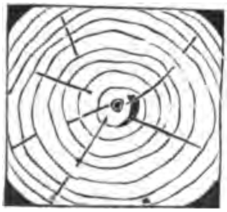


Fig. 225.

The pith or medullary rays, having their cells at right angles to the longitudinal fibres, as they dry, put a great strain on the latter. The lateral shrinking of the main fibres also is at right angles to that of the medullary rays, and those two opposing stresses subject the woody structure to a severe strain. In consequence of this, with rapid drying the pith rays separate and checks result.

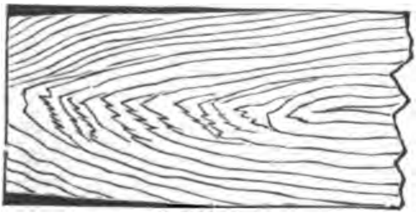


Fig. 226.

The obvious natural precaution is to season slowly and carefully. Lumber should be sawn *quarterly*, that is, the log cut through its centre twice with cuts at right angles to each other, boards afterwards being *cut at an angle of 45°* with the previous sawing.

Railway ties and similar balks should be cut from quarters and then squared up, so that *one corner of each piece is heart-wood.* This prevents checking and warping. Large timbers are prevented from twisting by sawing down the middle and placing the severed portions *back to back* with the *heart-wood outside.*

It has been stated that all timbers are nearly twice as strong when thoroughly seasoned as when dry.

Although it is the first shrinkage which causes checking, yet swelling and contraction, caused by subsequent absorption of moisture and drying, increase the effect of the original injuries. Soft woods, as pine, suffer less injury and distortion during seasoning than the harder varieties, as oak.

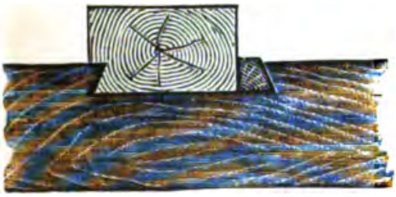


Fig. 227.

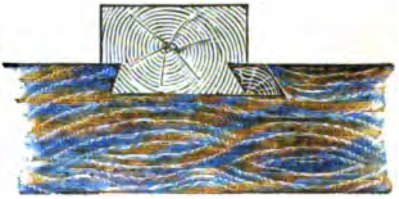


Fig. 228.

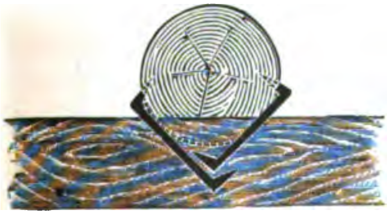


Fig. 229.

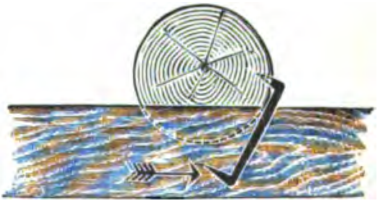


Fig. 230.

NOTE.—Temporary timber foundations besides being wedged together as illustrated in Figs. 227-228, are often fastened by means of *dogs.* Care should always be taken that they run obliquely across the intersection of two timbers, never parallel to it. The principle of the diagonal brace must be applied, each dog leaning in one direction having another pairing it which leans in the opposite direction, as shown in Fig. 229. If only one dog is used, as in Fig. 230, a force acting in the direction of the arrow will cause the timbers to work as on a hinge, quickly resulting in the foundation falling to pieces.

BRICKLAYER'S SCAFFOLD.

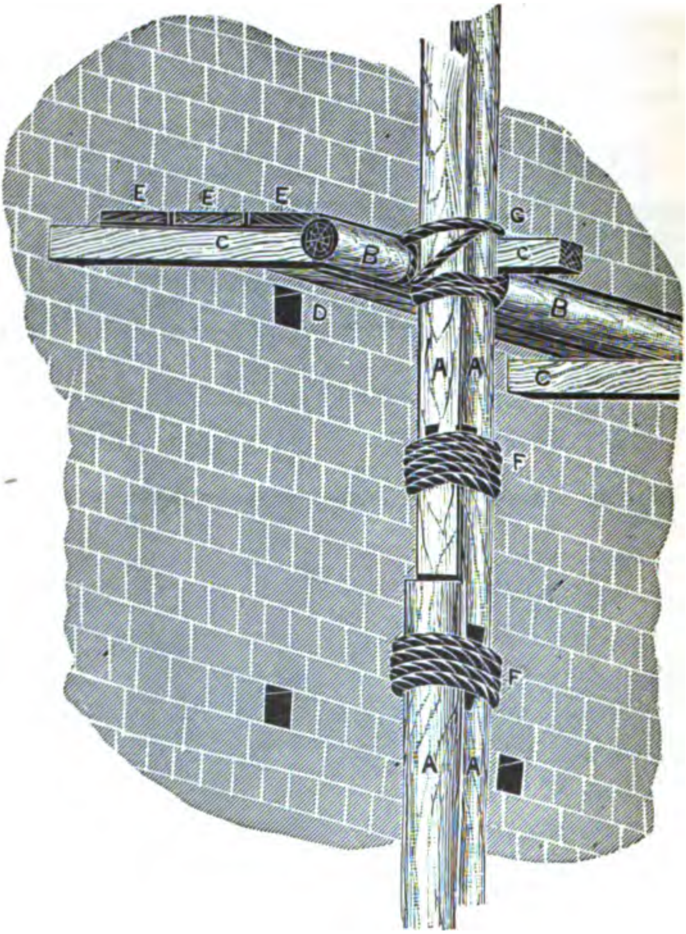


Fig. 231.

Explanation of Figure.—AA, standards; B, ledger or runner; CC, putlogs; D, putlog-hole; EE, scaffold-boards; FF, marrying.

SCAFFOLDING AND STAGING.

It is impossible for a man to do satisfactory work at a height greater than about five feet above the place whereon he stands, therefore some arrangement must be made whereby he can always stand in the same relation to a structure, as it rises above the ground. To this end, platforms of a more or less temporary character are erected in successive stages at regular intervals, providing the standpoint where work can be carried on and storage room for such materials and tools as are immediately required. This arrangement of platforms and supports is termed *scaffolding*.

The bricklayer uses poles of fir lashed together to form a framework parallel with the vertical plane of the wall. Horizontal support for the platforms is obtained by means of *putlogs*, or squared scantlings, one end of which rests in the wall, within an opening made by taking out a header brick, while the other end rests upon the runners or transverse members of the scaffold.

The stone-mason cannot use putlog holes on account of the larger size of stones as compared with bricks, hence to support the inner end of the putlogs a second framework is erected close to the wall, and as the weights of the materials are much greater, the whole structure is made much heavier and stiffer, with the poles spaced less widely. The arrangement of parts being otherwise similar, one description will serve for both.

The upright poles or *standards* are generally of spruce and run from 30 to 50 feet in length, with a diameter of 5 to 8 inches at

SCAFFOLDING.

the butt; they are spaced from 8 to 12 feet apart, the former distance suiting the mason's practice. The lower end is buried about two feet in the ground, or, if excavation is not permissible, it is placed in a large tub filled with earth so as to prevent shifting. The standards are placed 4′ 6″ from the wall, if putlog holes are to be used; if not, the inner scaffold is only six inches from the wall, and the outer at a distance of 5′ 0″.

For low buildings each standard consists of a single pole, but to attain greater heights, two poles of unequal length are lashed together side by side, the tip of one to the butt of the other, and tightened with wedges. Such uniting of two poles is termed *marrying*. Other lengths are added, care being taken that the joint in one pole is opposite the middle of its twin. Short scaffold poles, measuring about 2½″ at the tip and averaging 20 feet long, are known as *rickers*.

The transverse poles, called *runners* or *ledgers*, are fixed singly, parallel with the wall, at a height ranging from 3′ 6″ to 5′ 0″; the latter being more usual, and forming what is termed *scaffold height*. *Diagonal poles* are also lashed across every four standards, forming a St. Andrew's Cross; these last are known as *braces*, and considerably stiffen the work.

The lashing or *tying* is effected by means of *scaffold cords*, eight-feet lengths of 2″ manila hemp line whipped at each end to prevent unlaying. Galvanized steel wire is also frequently used. The operation of lashing is greatly aided by the use of the scaffolder's hammer; the cord being wound around the handle and the head used as a heel or fulcrum to strain it tight. The ends are fastened by passing them over and under three turns of the tying. The wedges used are made with one side flat and the other rounding; the latter are placed toward the cord, and serve to tighten all together. As cordage shrinks when wet and expands as it dries, examination should be made of these wedges as the weather changes.

The *putlogs* are made of birch, about 4″ x 3″, with a length of about 6′ 0″, spaced 3′ 6″ to 4′ 0″, and tied securely to the *ledgers.* The alternative use of *putlog holes* or double scaffolds has already been explained.

Scaffold boards run from 1½″ to 3″ thick and are usually about 12′ 0″ long by 9″ wide. They are made square at the ends, with hoop iron nailed on to prevent splitting. Frequently a hole is drilled near each end so that a rope can be passed through in hoisting, such hole being strengthened by a square iron plate around it. Planks often slip out of a sling when hoisted, and may kill a man.

Fig. 232.

Where the end of the plank comes, two putlogs are laid side by side, each supporting the end of a plank. This is a much better method than lapping the planks; and in no case should the end of a scaffold board be unsupported, for it may tip up when stepped upon, and cause a serious accident.

At the edge of each staging a vertical *guard board* must be fixed to prevent materials from falling over, and a *guard rail* or batten should be placed at a height of about three and a half feet to protect the workmen.

The *ladders* used with such a scaffold are not very large, especially when compared with the long ladders used in painting and repairs. Ladders are lashed together in series to attain any

SCAFFOLDING.

considerable height, or a shoe on the lower end of each fits into a square socket on the top of the ladder immediately below. Struts are placed at the middle of each length to prevent swaying. About 8" or 9" is enough interval between the rungs.

A sort of tower is generally built alongside the main scaffold, about ten feet square, and constructed similarly of standards and ledgers. This serves for hoisting purposes, and for storing materials, to be distributed as required. In connection with building lofty structures of reinforced concrete, skeleton towers are erected at various points alongside the walls, serving as elevator shafts. The reinforcing rods having first to be placed in position, the pillars or similar portions of a sky-scraper require to be built up in "forms" to a considerable height, often fifty feet or more, before any of the concrete is laid. These elevator towers being built beforehand constitute a characteristic feature of this type of construction. The concrete mass from the mixing machine is rapidly hoisted in tipping tubs containing a cubic yard or more, and discharged into the "form" at the desired points.

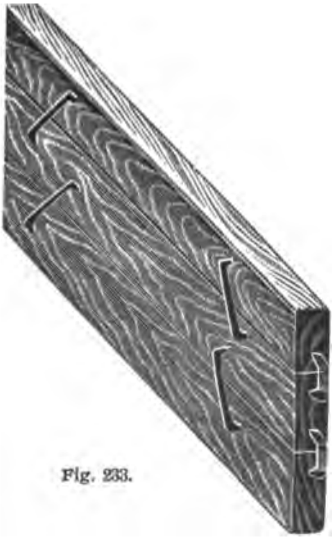


Fig. 233.

With the heavy weights, frequently concentrated into small compass, with which the millwright has to deal, he will generally require the stiffer, closer-spaced scaffolding preferred by the stone mason rather than the lighter framework of the bricklayer.

STAGING.

Where the work becomes really heavy, the characteristic scaffolding of the engineer is employed. This is variously termed *staging*, *gantries*, or *false-work*, and frequently demands as much thought and skill in its design as the structure about which it is employed. Sometimes it consists of steel trusses and lattice girders, but more generally consists of timber alone. These heavy framings consist chiefly of balks and large timbers. Stub tenons, joggles and the like, such as have been illustrated in Figs. 204 to 212, are used to prevent one member of the structure from slipping on its neighbor.

The use of bolts is costly, as they take time to fit and care to see that the holes, if previously drilled, come fair with each other. Also, as the holes must be a good fit to obtain the full value of the bolt, much time is consumed in driving the bolts into place, coupled with risk of damaging the threads. To avoid this, *dogs*, variously termed *timber* or *pinch-dogs*, as illustrated in Fig. 232, are used very largely.

The method of fixing these dogs will be gathered from Fig. 233, reference to their use having been already made on page 205 and illustrated in Figs. 229 and 230.

They are put in to connect two adjoining pieces, just the same as the joiner or pattern-maker uses his little dogs to join up temporarily the pieces of wood which he is gluing together. They are to be strenuously recommended for all save absolutely permanent work, as not only do they save time, trouble and labor, but also prevent the timber from spoiling with bolt holes, as in many cases the balks will be sold by the contractor on the completion of the work, and bolt holes greatly lessen their value.

Fixed stagings are erected of squared timbers, which are usually tarred for preservation. These timbers are usually termed *balks*, STAGING.

but become *standards* when vertical on land, and *piles* in the neighborhood of water. When erected on land, the ends of the standards are sunk into holes dug in the ground, and heavy stones are frequently loaded around these lower ends.

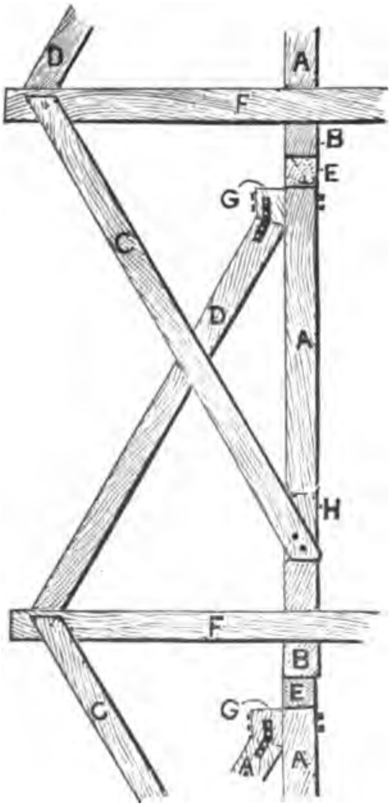


Fig. 234.

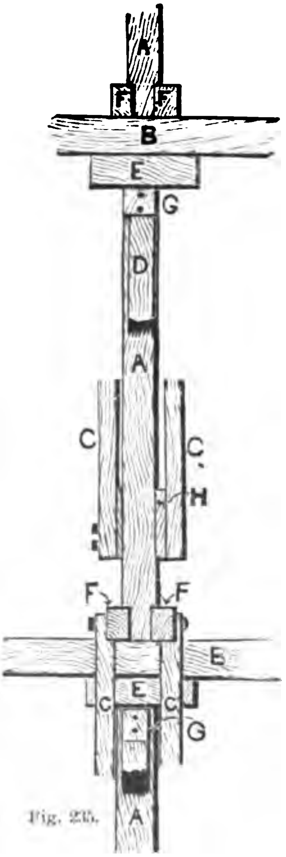


Fig. 235.

Although stub tenons are frequently used at the abutment of a strut or brace on its posts or beams, yet, with staging, they are rarely relied upon, and cleats or straining pieces as illustrated in

STAGING.

Figs. 234 and 236 are generally applied. The struts are, however, securely bolted or spiked to the timbers against which they come.

With these scaffolds, the *deck* or floor usually consists of three-inch planks carefully laid. A little interval must be left between each so that water will not be retained by the decking, but the openings should not be large enough to pass bolts, rivets or nuts. These latter falling from high structures are a fruitful source of serious accidents.

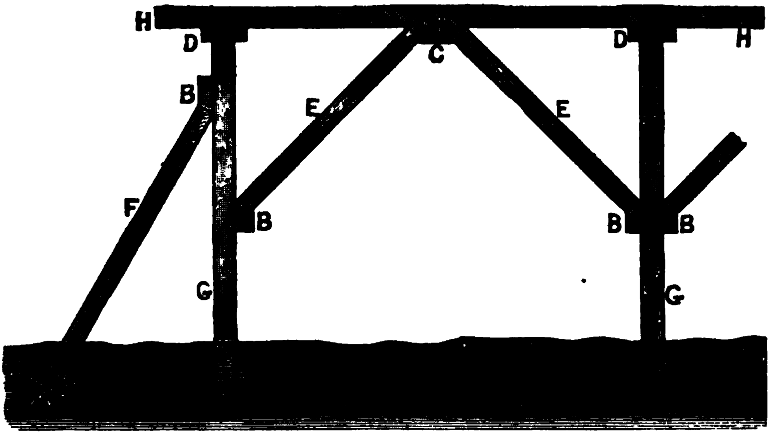


Fig. 236.

REFERENCES TO FIG. 236.—A, foot-block ; BB, cleats ; C, straining piece ; DD, corbels or cap-pieces ; EE, braces ; F, strut ; GG, standard or post.

Lateral bracing, as illustrated in Fig. 234, must be resorted to whenever a staging has to be carried up several tiers. The *cross-piece* corresponding to the *putlog* of the mason's scaffold is extended as at *F*, projecting for a distance of nine or ten feet. It serves as an abutment for the *upper struts D*, serving a similar purpose to the *foot-block* shown at *A* in Fig. 236; it is supported itself in turn by the struts *C C*.

GANTRIES.

It will be noticed that the staging illustrated is a composite of tiers, each unit of which greatly resembles that illustrated in

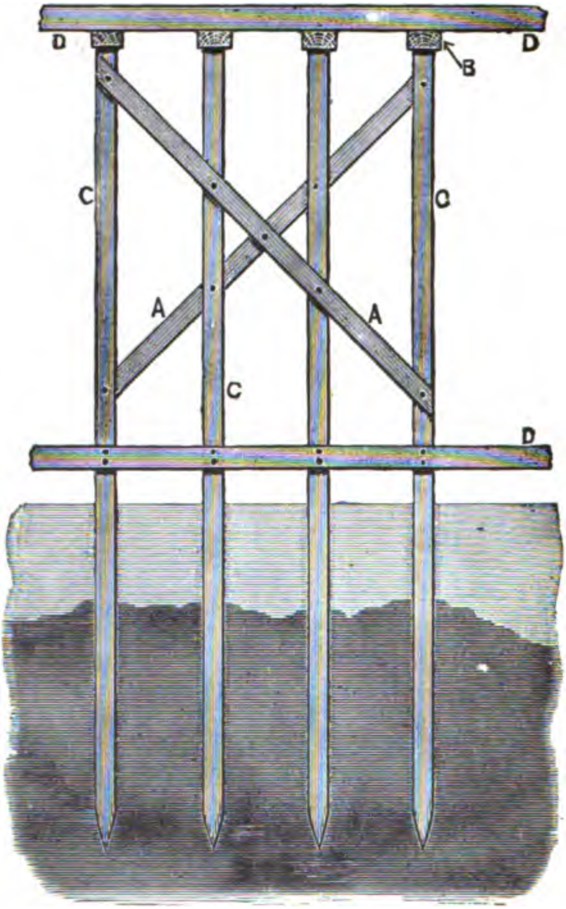


Fig. 237.

Explanation of Figure.—aa, diagonal braces; bb, cap-pieces; cc, piles; dd, runners.

GANTRIES.

Fig. 236. With such height *cross-bracing* is necessary; this is effected by means of diagonal timbers laid across the face of the structure.

Where heavy stones have to be lifted it is usual to construct a *gantry*, similar to that shown in Fig. 236, having provision for a travelling crane on its upper surface. The *standards G G* vary from 8″ to 12″ square, spaced from 10′ to 20′ centres. The top of each standard is provided with a *cap-piece*, *D*, which distributes the stresses more equally and gives the runners a better bearing. It is desirable to make the *runner*, *H*, as strong as or a little stiffer than the standards, the various *struts* or *braces*, *E E*, being half the sectional area of the standards. The braces abut on *cleats*, *B B*, at their lower ends, and upon a *straining piece*, *C*, at their upper extremities. These stays are affixed with bolts or iron dogs, mortises and notching being avoided as much as possible, so that the full strength of the timber may be maintained.

The strut or shore, *F*, abuts on a *foot-block*, *A*, which is buried at right angles to it. Frequently the foot-block lies horizontally, the strut thrusting against a cleat or shoe formed upon it, the whole being retained from slipping by a short pile driven alongside it. Occasionally the lower ends of the standards are tenoned into a *mud sill*, a continuous beam placed upon the ground with a view to prevent unequal settlement.

A simple structure, such as would be erected for works where piles were of necessity employed, is shown in Fig. 237, which also illustrates diagonal bracing and tying together horizontally by means of auxiliary runners laid along each side of the piles, and generally joggled into them. With such runners as these a substantial *splice-joint*, as Fig. 197, is employed; hardwood keys being freely inserted to assist the bolts.

TABLE OF WIRE NAILS AND SPIKES, ALSO CUT NAILS.

Ordinary Steel Wire Nails and Brads.						Steel Wire Spikes.			Ordinary Cut Steel Nails.		
		Common.		Finishing.							
Sizes.	Length, Ins.	Diameter, Inches.	Number Per Lb.	Diameter, Inches.	Number Per Lb.	Length, Ins.	Diameter, Inches.	Number Per Lb.	Sizes.	Length, Ins.	Number Per Lb.
2d.	1	.0720	876	.0583	1351	3	.1920	41	2d.	⅞	716
3d.	1¼	.0800	568	.0673	807	3¼	.1920	38	3d fine	1$\frac{1}{16}$	588
4d.	1½	.0985	316	.0720	584	3½	.2070	30	3d.	1¼	448
5d.	1¾	.0985	271	.0720	500	4	.2253	23	4d.	1½	336
6d.	2	.1130	181	.0858	309	4½	.2437	17	5d.	1¾	216
7d.	2¼	.1130	161	.0915	238	5	.2625	13	6d.	2	166
8d.	2½	.1313	106	.0985	189	5½	.2830	10	7d.	2¼	118
9d.	2¾	.1313	96	.0985	172	6	.2830	8	8d.	2½	94
10d.	3	.1483	69	.1130	121	7	.3065	7	10d.	3	72
12d.	3¼	.1483	63	.1130	113	8	.3310	6	12d.	3¼	50
16d.	3½	.1620	49	.1205	90	9	.3310	5	20d.	4	32
20d.	4	.1920	31	.1350	62	10	.3750	4	30d.	4¼	20
30d.	4½	.2070	24	.....	...	12	.3750	3	40d.	4¾	17
40d.	5	.2253	18	.....	....	.	.....	..	50d.	5	14
50d.	5½	.2437	14	.....	.. .	..	.....	..	60d	5½	10

Common brads differ from common nails only in the head and point. Spikes are made with chisel or diamond points; also with convex (snap) heads, or flat heads.

NUMBER OF BOAT SPIKES TO 200-lb KEG.

Length in Inches.	¼-in. Square.	$\frac{5}{16}$-in. Square.	⅜-in. Square.	$\frac{7}{16}$-in. Square.	½-in Square.	⅝-in. Square.	¾-in. Square.
3½	2380	....	....	...	...	...	..
4	2343	1671	....	...	...	...	..
4½	2200	1364	1039	...	...	. .	..
5	2030	1308	935	...	...	...	..
5½	1828	1175	880	...	...	...	..
6	1624	1115	710	562	433	...	..
7	1420	988	665	516	400	...	..
8	1220	849	602	453	337	...	..
9	....	....	519	409	305	...	..
10	...	....	468	369	297	182	..
12	. .	....	410	302	241	155	..
14	....	....	...	...	216	130	95
16	..	....	....	...	182	122	80

N. B. The smaller sizes of wrought spikes are put up in kegs of 150 lbs. weight, containing approximately three-fourths of the above numbers.

RIGGING.

With rigging and scaffolding, so much use is made of ropes and cordage that a knowledge of knotting and splicing is necessary. This is so self-evident that many contractors engage seamen to supervise these matters, or to execute work carried on at a height. The erector, however, will be well-advised if he make a study of the subject himself, and to that end the following description of the more common rope fastenings has been prepared.

As stated above, ropes and cordage are so peculiarly a sailor's province that nautical expressions must perforce be used. Accordingly a few explanations will first be given of terms used in this connection:—

Knot; a fastening of one part of a rope to another part of the same, by interlacing them and drawing the loops tight.

Bend; a fastening of one rope to another or to a ring, thimble, etc.

Make fast; to secure the loose end of a rope to some fixed object.

Seize; to lash a rope permanently with a smaller cord.

Hitch; a fastening of a rope simply by winding it, without knotting, around some object.

Splice; to connect ropes' ends together by unlaying the strands of each and then plaiting both up together so as to make one continuous whole.

Belay; to make fast the end of a tackle fall, etc., at the conclusion of a hoisting operation or the like.

Bight; the loose part of a rope between two fixed ends.

RIGGING.

Marline Spike; a long tapered steel instrument used to unlay or separate the strands of rope for splicing, etc., or for working marline around a seizing.

Serve; to lash with cord, etc., wound tightly and continuously around the object.

Haul; to heave or pull on a rope.

Taut; stretched or drawn tight, strained.

Parcelled; wrapped with canvas, rags, leather, etc., to resist chafing.

Yarn; fibres twisted together.

Strand; two or more larger yarns twisted together.

Lay; to twist strands up together as in rope making, the fibre or tow receiving a right handed twist to make yarns, yarns being laid left handed into strands, and strands right handed into ropes. Three strands make a hawser, and three hawsers are laid up into a cable.

The rope fastenings most necessary for the purpose of the outside engineer or millwright here described, have an illustration of each one which has been tested by an expert and found abundantly clear to show the mode of procedure.

Knots used for making loops on the ends of ropes come first in order, and these comprise :—

Slip Knot, (Fig. 238). Ordinary running noose, tightening as strain is applied.

Bowline, (Fig. 239). A most useful knot, making a loop that will not slip or tighten ; to be recommended for all purposes that it will fulfil.

Bowline on a bight, (Fig. 240). Used to make a loop in the bight of a rope, or with a doubled rope.

KNOTS.

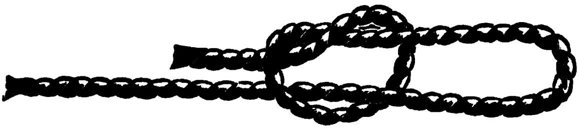


Fig. 238.—Slip Knot.

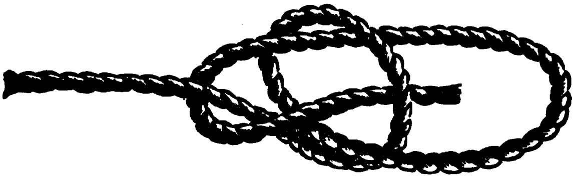


Fig. 239—Bowline.

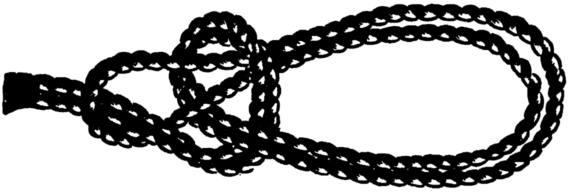


Fig. 240—Bowline on a Bight.

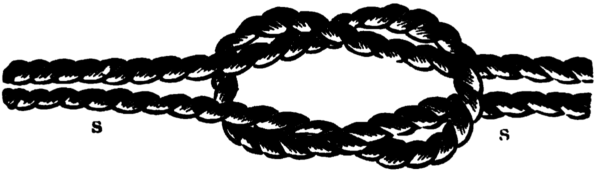


Fig. 241—Reef or Square Knot.

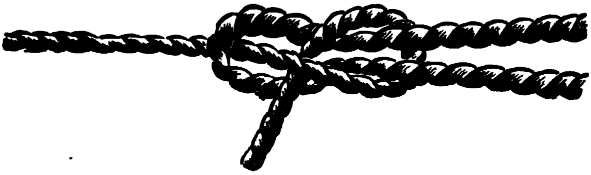


Fig. 242—Sheet Bend, or Weaver's Knot.

ROPE FASTENINGS.

Next in order come the *knots and bends used for tying two ropes together.* These are :—

Reef or Square Knot, (Fig. 241). Used to fasten the reef points of a sail ; a neat, non-slipping knot that lies quite flat, and is easily untied.

Sheet Bend or Weaver's Knot, (Fig. 242). For tying together two ropes of different sizes.

Carrick Bend, (Fig. 243). For connecting the ends of two equal ropes.

Various methods of *securing the ends of ropes* next demand consideration, and these vary greatly with the diversity of the object sought to be attained.

Clove Hitch, (Fig. 244). To make fast a line to a spar ; will stand a vertical pull without slipping.

Round turn and two Half Hitches, (Fig. 245). A simple means of making fast the end of a rope or block-fall. Supposed by sailors to be characteristic of an engineer.

Fisherman's Bend, (Fig. 246). A convenient and neat manner of making fast a rope's end, especially to a ring-bolt or cleat.

Round turn and Half Hitch, (Fig. 247). For seizing a rope to an eye-bolt or ring.

Blackwall Hitch, (Fig. 248). For making fast a rope over a belaying pin or crane hook, not very trustworthy.

Double Hitch, (Fig. 250). For similar purposes, but safer than the Blackwall hitch. Care must be exercised, with this hitch and the preceding one, that the strain comes upon the part of the rope marked S for strain.

BENDS AND HITCHES.

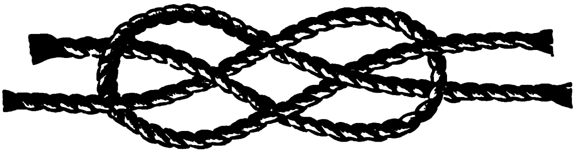


Fig. 243—Carrick Bend.

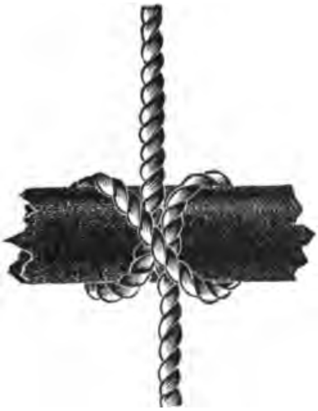


Fig. 244—Clove Hitch.

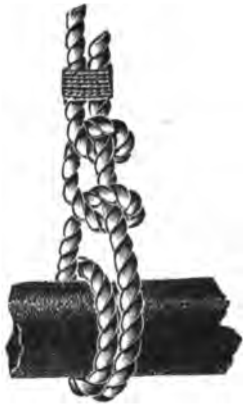


Fig. 245—Round turn and two half hitches.

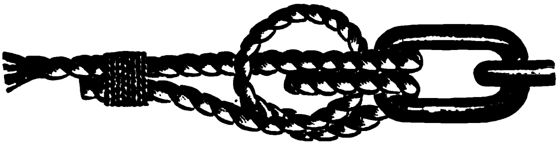


Fig. 246—Fisherman's Bend.

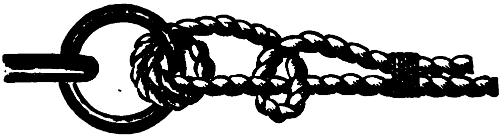


Fig. 247—Round turn and half hitch.

SPLICING

The methods of *splicing* two ropes together, by incorporating their strands together, differ according to the services required. Chief among them are:—

Short Splice, (Fig. 251). Quickly made; useful for strops or slings; makes a lump on the rope, and therefore is not recommended for driving or hoisting ropes. It is made by unlaying the two ends for a sufficient length, interlaying the strands so that each strand lies between two strands of the other rope, as illustrated; drawing the ends close, and pushing the strands of one over and then under the strands of the other for at least four strands.

Long Splice. Necessary for *main driving ropes* or for *block falls* which have to be rove through a pulley, and in which no increase of thickness is desirable. To make it, tie twine around each rope about six feet from the end, and unlay the end of each rope up to the twine, cutting out the central core upon which the strands have been laid. Interlaying the two ends together, as illustrated for a *short splice*, do not push the strands under each other, but separate the splice into parts, each strand being taken to a different place to maintain the even thickness of the rope.

It is usually convenient to twist the adjacent strands around each other to avoid entanglement. The first strand, termed No. 1 strand, is laid in the groove of the opposite strand of the other rope, this latter being unlaid for the other to be put in, the twine having been untied to permit this. Care must be taken to maintain the twist. About four feet is sufficient for the splicing, the strands being temporarily tied, each in its place.

The next strand to No. 1 is, of course, No. 2, but it must not be touched until No. 3 is finished in the same manner as No. 1;

SPLICES.

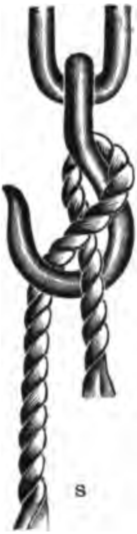


Fig. 248.
Blackwall Hitch.

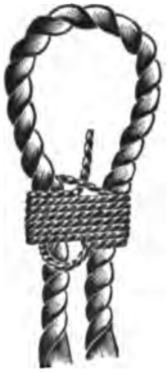


Fig. 249.
Round Seizing.

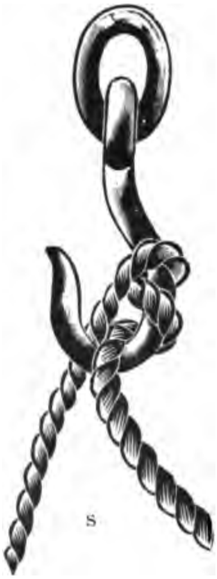


Fig. 250.
Double Hitch.

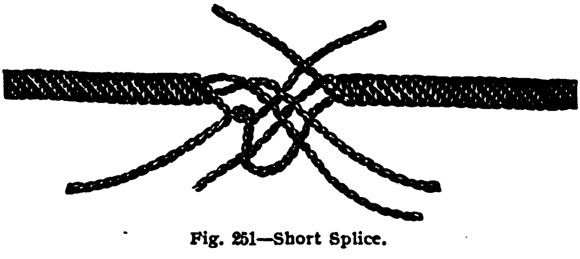


Fig. 251—Short Splice.

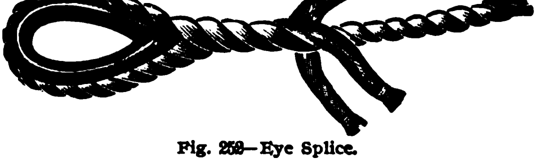


Fig. 252—Eye Splice.

with this strand eighteen inches to two feet is sufficient, instead of four feet, as with the first.

Assuming that Nos. 1 and 3 strands have been part of the *right-hand* rope, and have been laid up on the left-hand one, it will be necessary to reverse the process for the two remaining strands. In other words, unlay No. 2 and No. 4 from the right hand rope, and lay up in their place Nos. 2 and 4 strands of the *left-hand* similarly to No. 1 and No. 3; doing one at a time, of course, and seizing the ends as soon as enough has been laid.

The eight ends must now be shortened to equal lengths, say a foot, and reduced by about one-third of their yarn, the seizings removed in turn, as each end is twice laid over its mate, for an over-hand knot, with the marline-spike, finishing off by drawing the end through the middle of the rope, and trimming all ends off.

NOTE.—A *wire rope* may be spliced in practically the same manner. Some six to eight feet for small sizes, or proportionately longer for larger wires, is marked off, tied with marline, and unlaid as with rope, the core being cut out. As the strand in one rope is unlaid, the corresponding strand from the other is laid in its place; each meeting point should be temporarily tied, and the ends cut off to a similar length. Care must be taken that the succeeding pairs of strands stop well short of the preceding ones. When all the pairs of strands are tied and in place, the rope should be taken to a vise and untwisted by hand beyond the outside pair of strands. As the rope opens, an assistant with nippers must cut the core, and as he slowly pulls it out, the operator must follow with the wire end, tucking it into place. The rope is then allowed to close on itself, and untwisted further along, pulling the core out in the opposite direction and crowding the wire into its place. These operations are performed in succession at each meeting place of two strands; the rope being hammered lightly with wooden mallets at the spliced points to make all lie smooth.

Some seamen simply tuck the ends through the centre and out the other side, cutting the protruding wires; this, however, is not such a finished method as the first described.

KNOTS AND HITCHES.

After splices, consideration must be given to methods of *fixing ropes around thimbles or bars*. Three good styles are:—

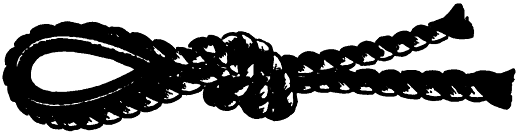


Fig. 253.—Flemish Loop.

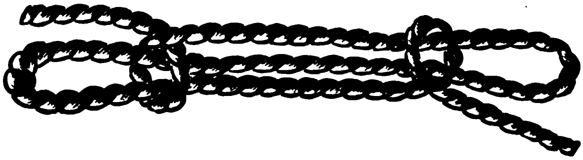


Fig. 254—Sheep Shanks.

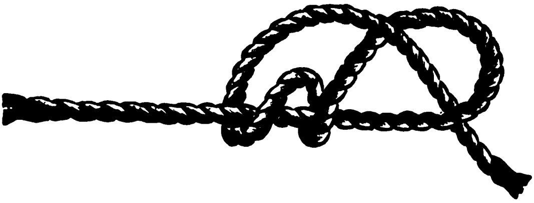


Fig. 255—Stevedore's Knot.

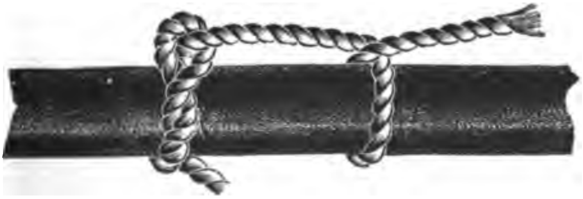


Fig. 256.—Floating Spar Hitch.

Eye Splice, (Fig. 252). The permanent method of bending a rope around a thimble or grummet: the loose end is spliced into the centre of the rope.

KNOTS AND HITCHES.

Flemish Loop, (Fig. 253). A neat and safe method of temporarily fixing a thimble in a rope, with a slip-noose and round turn.

Round Seizing, (Fig. 249). An attractive style for making a permanent loop in a rope.

Occasionally it is desirable to *shorten a rope* considerably without having recourse to cutting it; for such purpose the *sheep-shank*, shown in Fig. 254, is invaluable.

The last series of fastenings are those used for *connecting block-ropes, etc., to the objects which have to be lifted.* Among them are:

Strop or Sling, (shown in Fig. 79 on p. 101). An endless rope made by splicing; the illustration shows its application to an object whose end is inaccessible, or which has no eyes to hook into.

Stevedore's Knot, (Fig. 255). For making fast a block-rope to the handles or cord of a package.

Timber Hitch. For hoisting, etc., cannot slip; the harder the pull, the tighter it grips. This will be seen in Fig. 78, on p. 101.

Timber Hitch and Round Turn, (Fig. 256). Useful for towing a spar, or for lifting one endways; specially adapted for standing a lengthwise strain; this is sometimes termed the *floating spar hitch.*

Lashing with Knot, (Fig. 257). A convenient method of improvising a sling.

Wire ropes if made "flexible," that is, with a hemp core to each strand and a central hemp core to the rope itself as well, will stand a strain in lbs. equal to the square of the circumference in inches multiplied by 600. That is to say, a rope termed "three-quarters," that is, with a diameter of about ¾ inch and a circumference of 2¼ inches, will stand safely 3037.5 lbs., having then a factor of safety of seven.

Wire ropes need to be kept clean from rust, etc., and should be lubricated when running; graphite being as good as anything. Once a month the rope requires to be carefully oiled with raw linseed oil, well rubbed in.

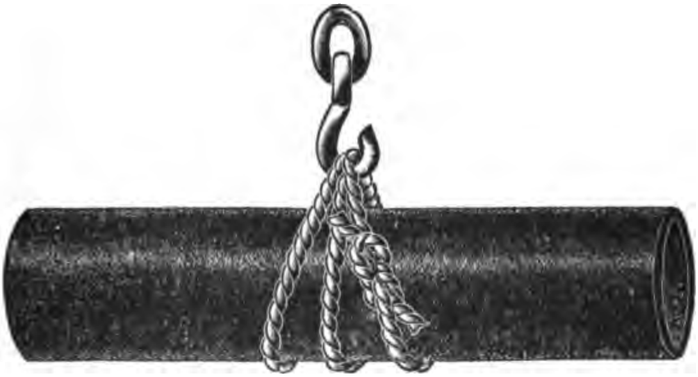


Fig. 257—Lashing.

So-called flexible wire ropes should *not be worked* around a sheave or drum having a less diameter than *six times the girth* of the rope; harder and stronger ropes, such as are used for winding from great depths, should not pass over any wheel of a less diameter than *ten times the girth.* The smaller figures are for ropes worked at a slow speed only; for each increase in speed the pulley should also be enlarged. This must specially be insisted upon with *elevators* and *lifts*, in which case it is advisable to exact *ten* as a minimum ratio.

INSPECTION OF ROPES.

A few words must be said on the care of ropes. Hemp is easily rotted by the influence of damp; hence, if the ropes have been used in the rain or allowed to get into water, they must be hung up to dry. A beam within a shed, some eight or ten feet above ground, is most convenient for this purpose, the rope being passed over it from one side to another, and hanging down in loose festoons on each side *well clear of the ground.* This facilitates the circulation of the air around each part of the rope. *On no account* should a rope be coiled up when wet, as the internal covered parts absorb all the moisture, and quickly rot.

Constant inspection is necessary, as unlooked-for damage may be occasioned by the parting of a rope. A good method of inspecting the inside fibres is by partially untwisting the strands by moving each hand in opposite directions as they hold the rope; this gives an opportunity of examining the under side of the strands.

The strain and chafing cause rupture of the fibres, which must be seen to. Much of this trouble may be obviated in the case of standing ropes by using "parcelling," or chafing-gear, of rags, marline or leather bound around the rope to protect it.

Always suspect a rope that has lain in a warm place, such as a boiler house. It may have "perished," and is not trustworthy.

Ropes that have to be exposed to wet are rendered more durable by coating the yarn with Archangel tar in the process of making. This, however, reduces the strength of the rope by one-fourth.

It may be advisable to state here that rope-makers generally specify all their manufactures in terms of *their circumference,* and the various formulas for weight and strength are all calculated from that dimension.

CHAINS.

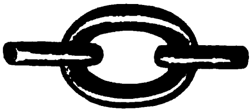


Fig. 258.

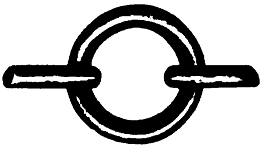


Fig. 259.

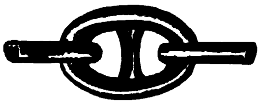


Fig. 260.

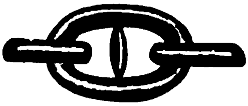


Fig. 261.

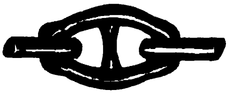


Fig. 262.

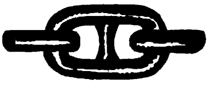


Fig. 263.

Chains are made of round bar-iron or steel forged into links, by bending to shape and welding.

The illustrations represent different kinds of links; Fig. 259, the circular open link; Fig. 258, the oval link. Figs. 260, 261, 262 and 263 show the oval stud link with broad headed stud, the same with pointed stud, the obtuse-angled and the parallel-sided stud link; the latter is the more frequently used.

The stud is a distance piece, usually of cast steel, which serves to strengthen the link; it is used on the larger sizes alone and permits a longer link. Most chains for heavy stresses are made this way.

Fig. 264 shows a close link chain sling, having a large open circular link in which the hook engages. A length of stud chain is illustrated in Fig. 269, and is noteworthy on account of the swivel in the middle of its length, permitting rotary motion without fouling the chain.

Turnbuckles are generally used to strain both chains and ropes taut, Fig. 265 being what is termed a hook-and-eye turnbuckle adapted for tightening the shrouds or guys of a flagstaff post or derrick. Fig. 266 is an ordinary type of turnbuckle, sometimes known as a stretching screw, provided with right and left hand threads to tauten stays, etc.

A chain or cable shackle as seen in Fig. 267, is used for connecting lengths, usually 15 fathoms, of a cable; the bolt has a countersunk head and is locked by a wooden or brass taper pin, as iron would rust in. Fig. 268 represents the common anchor shackle, in which the pin is attached by a cotter or fore lock; this type is occasionally termed *clevis.*

Chains, both stud and close link, should be obtained from reliable sources. In view of possible deterioration and the severe strains to which they are subjected, crane chain slings, etc., should not be worked above a safe load.

Crane chains require to be taken off twice a year and annealed; that is, placed in a muffle or reverberatory furnace, brought slowly to a red heat, and cooled off gradually, covered the while with ashes or sand to exclude the air. This process is rendered necessary on account of the crystallization or alteration of fibre set up in the metal by the constant jar and reversal of strain. Broken crane chains often exhibit a granular fracture like cast iron. Running chains should be lubricated with blacklead (graphite) mixed with tallow, and care should be taken to arrange all leads so that no "nips" should occur, as these are very destructive and shorten the life of the chain considerably.

A supply of split or patent links for each size of chain in use should be kept by the storekeeper of the erecting gang, as much time is lost in binding the two ends of a broken chain together with wire. Shackles of course can be used for the larger sizes in cases of need.

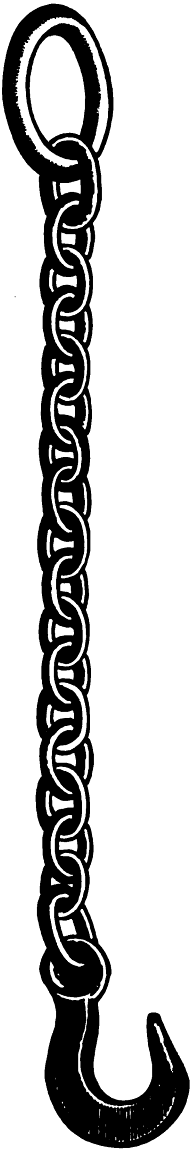


Fig. 264.

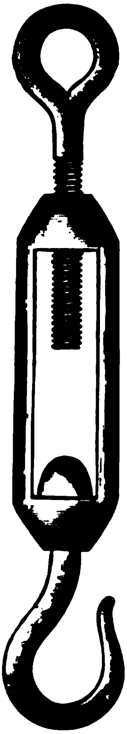


Fig. 265.

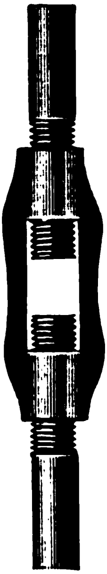


Fig. 266.

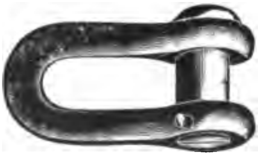


Fig. 267.

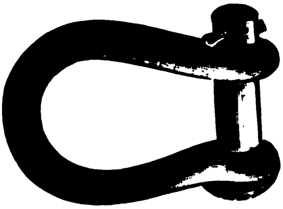


Fig. 268.

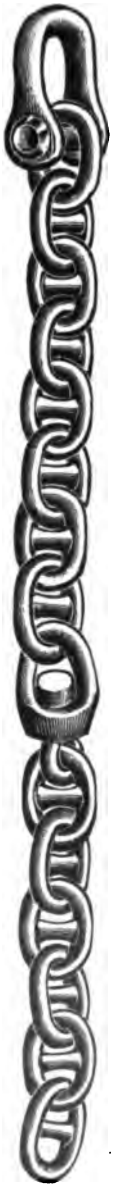


Fig. 269.

COMBINATION OF PULLEYS.

For lifting heavy weights recourse is had to the mechanical power known as *the pulley*, consisting in its simplest form of a grooved wheel rotating on an axis. The mere passing of a rope over one fixed pulley for hoisting a weight does not give any increase of power, the force necessary to sustain the weight being equal to the latter, plus friction of the rope, etc.

The gain consists altogether in more convenient application of the power exerted, as it is easier to haul downwards on a pull of 100 lbs. than to lift 100 lbs. directly from the ground. This may be termed *mechanical advantage* as apart from *multiplication of power.*

When, however, one end of the rope is fixed, passes *under* the single pulley to which the weight is attached, and the free end is lifted, the travel of the rope or cord is double that of the weight, and the power necessary to sustain the latter is half the weight plus friction. It may be stated in the reversed proposition, that with a *movable pulley* the weight capable of being lifted is *twice the force applied* minus the friction of the apparatus.

Combinations of pulleys are arranged with several sheaves in one case, to form a block to secure this multiplication of power. The upper or fixed block gives the mechanical advantage of application, and the lower or movable block, by multiplying the travel of the rope as compared with that of the weight, increases the power in proportionate ratio. Each movable pulley halving the power necessary, with two sheaves the force necessary is one-half of one-half, or one-quarter. Briefly, the weight capable of being lifted is equal to the force multiplied by twice the number of sheaves in the lower block, or by the number of "runs" of rope around them, which is the same thing; the friction of the tackle having to be deducted.

GAIN IN MOVABLE PULLEYS.

Examination of the block and tackle shown in Fig. 271 will make this clear, the arrow heads showing the direction of travel of the rope, or *fall*, as it is termed. The thin cord shown manipulates a patent brake, seen in the upper block, which locks the rope should it be desired to suspend the object lifted.

It will be evident, upon consideration, that no two sheaves travel at the same velocity, on account of the varying speed of the different parts of the rope. *It is therefore requisite that the sheaves be independent of each other*, revolving loosely upon a spindle fixed in the shell or frame of the block.

A basal factor of all mechanical powers is, that *whatever is lost in time is gained in power*, or the reverse. It has been seen that with the weight travelling half as fast as the rope, double the weight could be lifted with the same force, or a force of only half the weight was necessary. This principle is made use of in every direction, as, for instance, in the gearing used on a machine-tool to translate the high speed at which the belt travels into the slow speed and great power necessary to cut off the steel from the forging which is being operated upon; or in the small wheels fitted to a freight locomotive so that the pistons may make rapid strokes although the speed of the train be slow.

With a hydraulic elevator or crane, this very arrangement of pulley blocks is used in the reverse method, to convert the slow, powerful thrust of the ram into the high speed at which the rope, and consequently the cage or weight, moves.

The *differential pulley block*, shown in Fig. 270, depends for its utility upon giving a very slow travel of the weight in comparison with the speed of the haul. This is secured by making the two upper pulleys of nearly the same size, the endless chain being *paid out* by one while it is *hove in* by the other. In other words, the smaller sheave tends to lower the weight while the larger one raises it, the total lift equalling the difference of circumference of the two sheaves. Assuming in this case that there are 25 sprocket teeth in the larger sheave and 23 in the lesser, the velocity of haul as compared with that of the lift will be $\frac{2 \times 25}{25-23}$ or 25 to 1, consequently a pull of 80 lbs. will lift 1 ton of 2,000 lbs. This style of block is fitted with an endless chain, which obviates a serious objection to the principle of the differential windlass, namely, the great length of rope required if the displacement of the object moved is to be very large.

As the differential tackle is liable to mishaps in use, such as jamming of the chains, or slipping the load on jerking, and has the serious defect of having only a certain length of chain, which precludes long lifts, other contrivances have been designed to attain the same ends. The most successful is the worm gear as shown in Fig. 272. An endless chain, passing around a sprocket or *gipsy wheel*, rotates a worm, and, by multiplying gearing, hauls on the lifting chain. In the illustration this will be seen to be double, for giving a steady lift, and it is raised or lowered by the small gipsy wheels seen to the right. Not only is the gain of power, at the expense of time, obtained by the multiple gearing of this device, but the *worm prevents slipping*, and as there is no weight on the hand chain *a jam is not dangerous.*

NOTE. Another type of pulley-block, known as the *Triplex*, using *Spur-gearing*, has distinct hand and hoisting chains with separate gipsy wheels, mounted upon concentric spindles. The mechanism is a sun-and-planet-train, and, being constructed with a view to minimize friction, it is said to handle heavier loads at a greater speed than other patterns. An ingenious arrangement of ratchet-plates and brake-discs, controlled by the hand-chain wheel, is used to hold the load and regulate the lowering.

DIFFERENTIAL TACKLE.

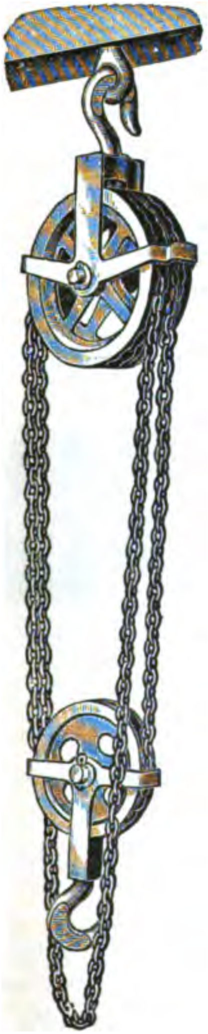


Fig. 270.

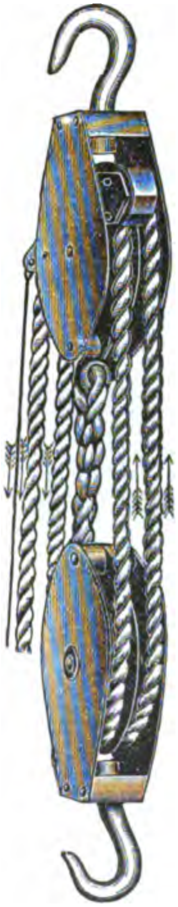


Fig. 271.

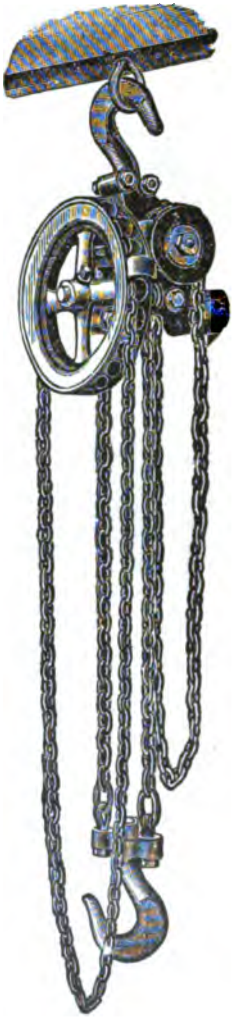


Fig. 272.

IRON SHEAVE BLOCKS.

Fig. 273 represents a single-sheave, Fig. 274 a double-sheave and Fig. 275 a three-sheave, iron block of customary design. These united to form a tackle similar to Fig. 271 are used for handling weights by manual power, the lower block generally having one sheave less than the upper. The standing end of the rope is seized to the becket of the lower block, rove first through the upper, then the lower, and so on until the fall finally depends from the upper.

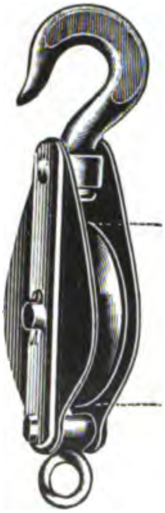


Fig. 273.

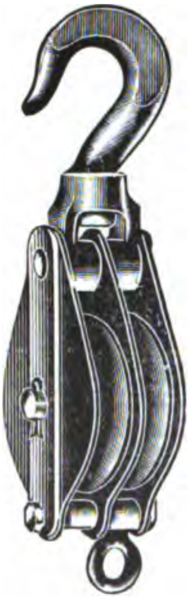


Fig. 274

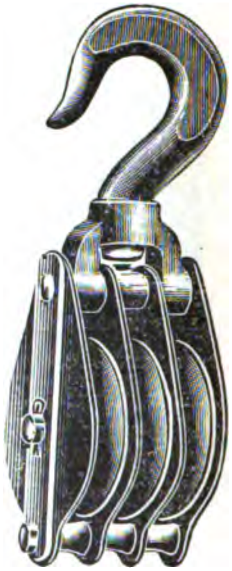


Fig. 275.

Wooden blocks are used out of doors in preference to iron ones, in connection with derricks, gin poles or rigging, as they will stand the weather and rough usage better. The sheaves are of brass or of lignum vitæ bushed with bronze, working on a steel pin.

BLOCK AND TACKLE.

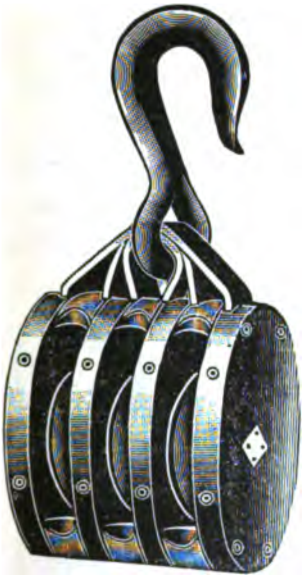


Fig. 276.

A three sheave upper block is illustrated in Fig. 276, and a double sheave lower block in Fig. 277, both uniting to make a pair of blocks, commonly termed a block and tackle, or more briefly still a "tackle." Many persons denominate blocks by the number of times the rope or *block fall* passes the lower pulleys, consequently the tackle in question would be known as a *four run block.*

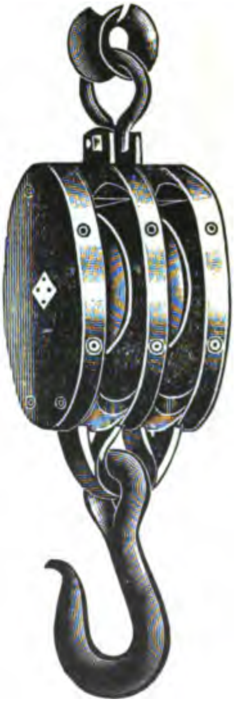


Fig. 277.

On page 232, in considering the gain from a system of pulleys, it is stated that the ratio of purchase was equal to the number of runs around the lower or movable block. This is not quite exact with a compound system similar to Figs. 276-277, wherein examination will show a *five-fold gain*, or equal to the *number of parts of the rope supporting the lower block.*

Pulley blocks have frequently to be used as fair leads or guide pulleys, for a block fall to a winch or capstan, when the pull is not in a straight line; and in that connection it is very inconvenient

SNATCH BLOCKS.

to have to reeve or unreeve a long rope through the sheave. To save this trouble, part of one cheek of the block is made to work on a hinge or joint, forming a *snatch block*, three types of which are illustrated below.

Fig. 278 is locked by a link and bent pin, which latter is turned around to release the latch. A common iron snatch block is shown in Fig. 279, the cheek swinging clear to get the rope in or out, locking on a wedge and fastened by a split pin. The usual type on shipboard has the movable part working on a hinge, and locking by means of a forelock or cotter thrust through a pin protruding from the fixed part through a hole in the latched portion. Fig. 280 shows what is known as the burr pattern, the hinge being locked by means of a wooden pin.

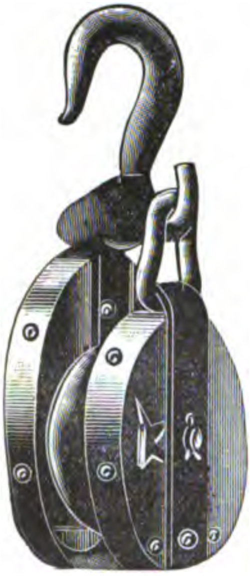


Fig. 278.

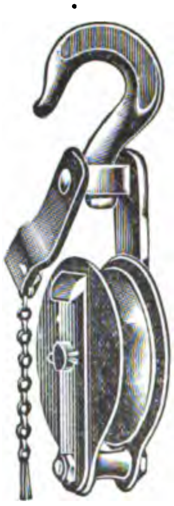


Fig. 279.

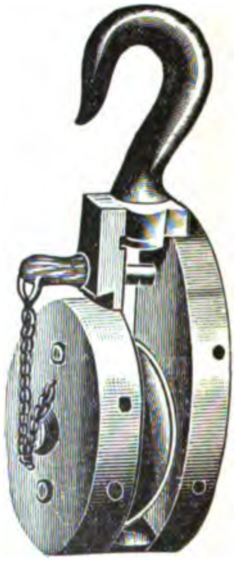


Fig. 280.

GIN POLES.

Erectors will find the *gin pole* of great use ; this is a stout pole, of a length corresponding to the object desired to be operated upon, which serves as a portable derrick to place upon their foundations objects which occupy a vertical position, such as iron chimneys, flagstaffs, etc.

The gin pole which is illustrated in Fig. 282, is pivoted at its butt-end on a bar which is lashed to two firmly driven stakes, close beside its desired position, and it is then hoisted into a vertical position by pulling on its guy ropes, and by men "walking it up" underneath, from the tip downwards. When vertical, it is firmly guyed to four stakes or "dead men" at convenient opposite points, and the lengthy object to be lifted is slung about its centre of gravity (preferably a little above) and, by hoisting on the gin pole tackle, and hauling on or paying out steady-ropes, it is easily manœuvred into position.

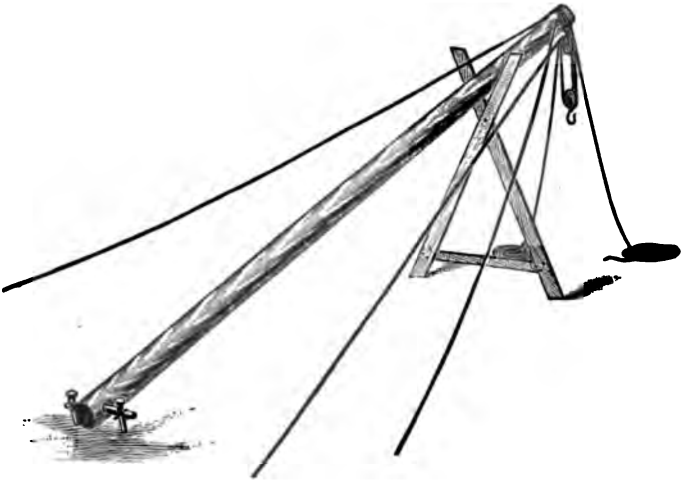


Fig. 281.

HOISTING GIN POLE.

The manner in which the gin pole is placed into position will be gathered from Fig. 280; it will be noticed that the outer end is temporarily supported on a trestle or horse, to save distance in "walking up."

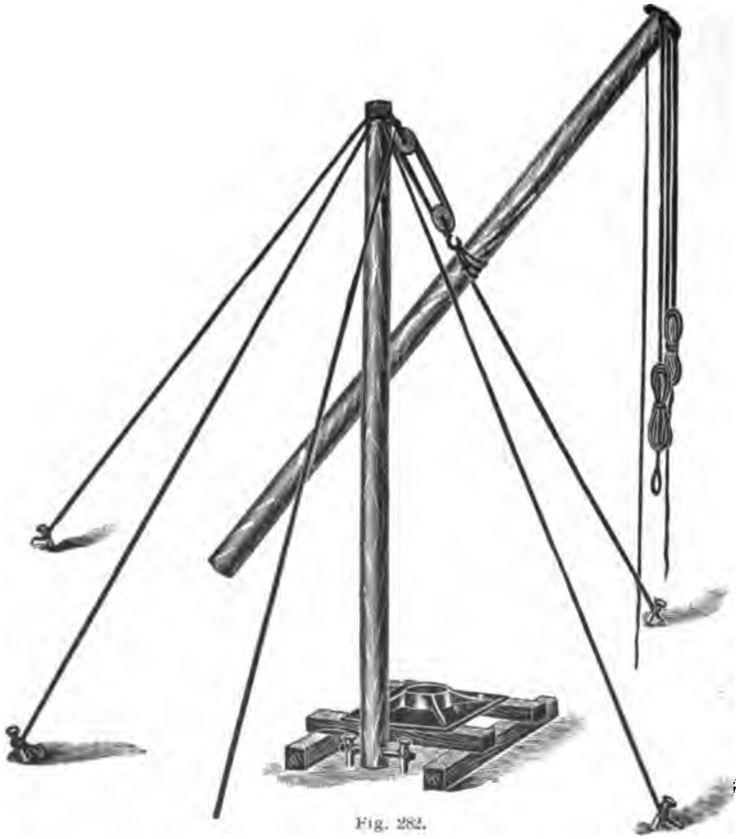


Fig. 282.

For fixing the stakes or "dead men," some little trouble must be taken, as a simple driven peg will not have sufficient holding power. A cross is made of stout wooden planks two or three feet long, the arms connected by a long eye-bolt or plain bar with

SCREW ANCHOR.

enlarged head; the part of the bolt which passes through the cross arms being threaded and fastened above and below the planks by lock nuts. The ground is dug up, the cross arms buried to a depth of some three feet, with the eye bolt or swelled head protruding well above the surface. The earth is well rammed down into the ditch to increase holding power.

A better contrivance is the *screw-anchor*, as illustrated in Fig. 283. This consists of a cast iron helix some twelve inches in diameter, with four inches pitch. The screw is "cast on" a wrought iron or steel shank of one and a half inch square section, which is suitably jagged to grip the cast metal. The shank is about six feet long, terminating in a three inch eye.

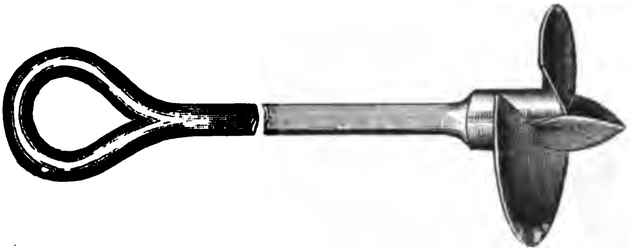


Fig. 283.

This anchor is worked into the ground in similar fashion to a screw pile, and possesses remarkable holding power—one having successfully resisted a pull of 36000 lbs. under test when buried five feet in clay. Its superior hold is attributed to the fact that the surrounding earth is not disturbed in inserting it. Another advantage is the short space of time required to insert it as compared with digging a ditch for a "dead man" or other anchor.

GAFF JOINTS.

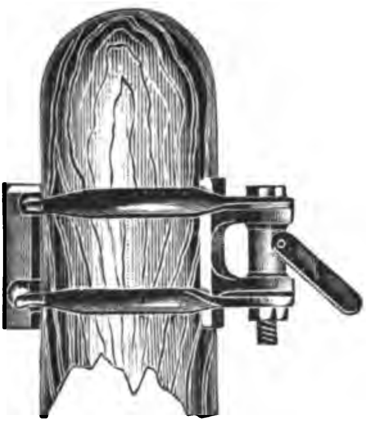


Fig. 284.

Besides gin poles, swing derricks are used, to serve the purposes of cranes, etc. They consist of a fixed upright part and a moving arm, the connection being made by universal joints. A good type of *gaff joint* is shown in Fig. 285 affording a fulcrum on the upright portion or mast for the movable arm, termed variously gaff, boom, or jib, and permitting it both horizontal and vertical motion through wide angles.

The *gooseneck*, as fitted to derricks on shipboard, is more serviceable in lifting heavy weights. The "pintle" or eyebolt revolves in the bracket or clamp upon the mast, and is prolonged to the base of the latter, thus relieving it of much thrust.

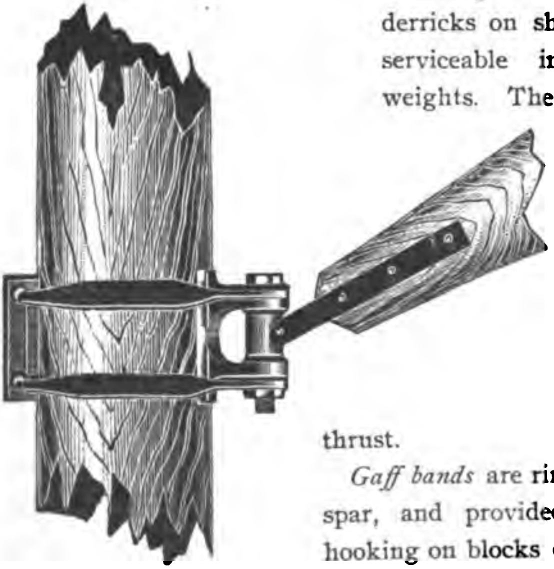


Fig. 285.

Gaff bands are rings encircling the spar, and provided with eyes for hooking on blocks or attaching guys.

GAFF BANDS.

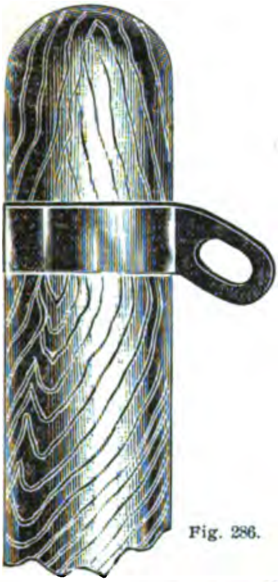


Fig. 286.

They are sometimes cast, but generally forged. Fig. 286, illustrates a single eye band, used in connection with the "topping lift" at the extremity of the gaff, or on the top of the mast for a preventer. The double eye, as in Fig. 287, serves for blocks both above and below the swinging arm and thus is generally more convenient, affording, as it does, connection for the purchase, or peak block which sustains, raises or lowers the derrick, and also for the blocks used to raise the weight. Another variety has four eyes, the two on either side serving to attach the *vangs* or *guys* used to slew the gaff.

In order that the derrick may swing as easily as possible, it is necessary to step the mast or upright post, in a perfectly vertical position.

The small universal joint, Fig. 284, is greatly to be recommended as it affords an easy attachment, in vertical line with the heel, for the *peak halliard block* which sustains the arm, and permits it to slew without nipping the rope at all.

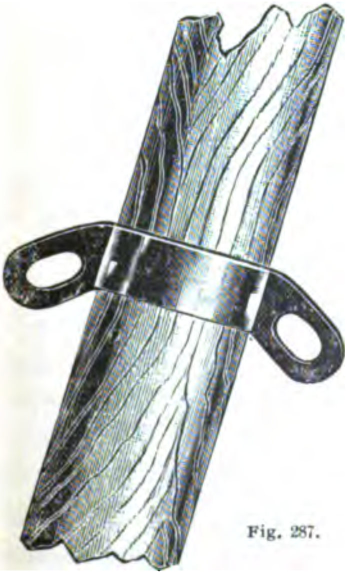


Fig. 287.

ROPE WEIGHTS.

An arrangement of parts about a derrick may be devised as follows. The band shown in Fig. 286 is fixed at the extremity of the gaff, serving to attach the *vangs* for slewing it. Another band, similar to Fig 287 is placed a little further back, engaging with the lower peak-block and the hook-block used in raising the load. The peak halliard is made fast to the upper peak-block, fixed at the masthead to a universal joint like Fig. 284, passes through the lower block hooked on to the band shown in Fig. 287, and after being rove through the upper block once more passes to the foot of the mast and is there made fast.

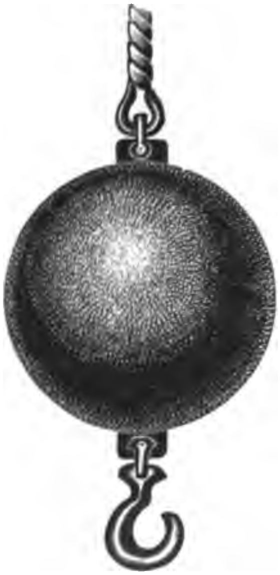


Fig. 288.

The wire or manila rope for hoisting is provided with a *rope weight* or *cowsucker* (shown in Figs. 288 and 289) to cause it to run of its own weight without overhauling, and a hook for attaching to whatever has to be lifted. The hoisting rope passes through the *hook block* on the band, (Fig. 287); and again through a *lead* or *throat block* hooked similarly at the butt of the derrick arm near the joint, going finally to the winch. With moderately heavy lifts, it is customary to substitute a close-link chain for the rope.

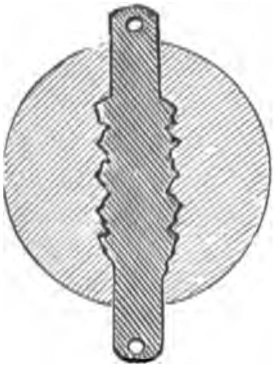


Fig. 289.

CRAB WINCH.

Where steam is available a steam-winch may be installed, but it is frequently possible to use hand-power only. To utilize this to its best advantage a *crab* or hand-winch as Fig. 290 should be supplied. The machine illustrated is fitted with a brake for lowering; a latch, seen near the further frame, holds the pinion or crank-shaft in gear. When desiring to lower, the load is held on the brake, the latch lifted, pinion-shaft thrust to the right out of gear and locked, the load being lowered on the brake without the handles revolving.

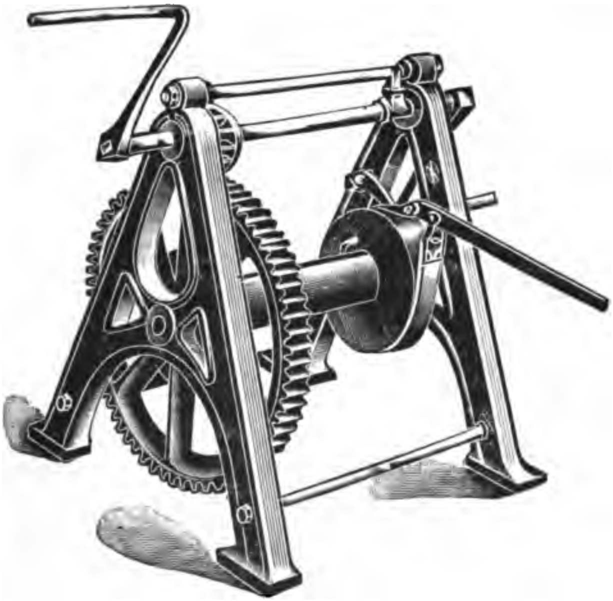


Fig 290

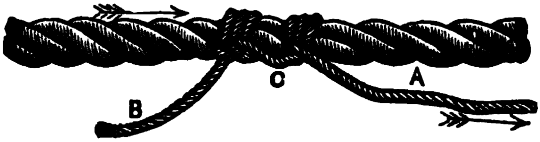
When using a winch of this description for wire rope, the barrel or drum should be at least twenty times the diameter of the rope, as has already been mentioned on page 227. This is to prevent the individual wires from being broken by passing through too sharp an angle.

STOPPER ROPES.

In hauling or hoisting by means of a winch, a rope has often to be made fast to a bitts, deadman or moving post, while yet it is under strain. The rope cannot be taken off the winch without relaxing it, and the operation calls for the interposition of a *stopper.*

This is a short length, eight to ten feet, of a two-inch manila rope, and its method of application is shown in the accompanying illustration. An eye is spliced in one end of the rope beforehand, as in Fig. 252, although it is not usual to insert an iron thimble.

Taking hold of the eyed end of the stopper rope marked A in the figure, with the *left hand* (the strain on the large rope coming with the arrow from that direction), the operator makes three *round turns* to the right, brings back the end, takes three *half hitches* to the left as at B, and passes the end A through the loop at C, to complete the fastening.



The bight of A is passed through the eye, making a *slip knot* (Fig. 238), and this being placed over the post or bitts, the strain on the winch can be eased and the end of the large rope taken to the post and made fast. It will be necessary that a strain, opposite in direction to the arrow, be maintained upon the end B, to keep the stopper knot from slipping. As soon as the main rope is secured, this end is relaxed and the stopper will at once slacken and can be easily undone.

RIGGING.

In similar manner, a fresh strain can be taken, with a winch, upon a rope or guy already tautened under a load. Instead of the short stopper rope, an ordinary line is used and the same fastening made. The part A is taken to the winch, both pulls going in the direction of the arrows in the illustration. This enables the strained rope to be loosened, and then made fast afresh, etc. As before, the loose end B must be kept taut by a backward pull.

TABLE OF STRENGTH OF CLOSE-LINK CHAINS.

Diam. of Rod from which links are made.	Weight of Chain per foot run.	Breaking Stress of Chain.	Safe Load on Chain.	Diam. of Rod from which links are made.	Weight of Chain per foot run.	Breaking Stress of Chain.	Safe Load on Chain.	Diam. of Rod from which links are made.	Weight of Chain per foot run.	Breaking Stress of Chain.	Safe Load on Chain.
Ins.	lbs.	tons (2000 lbs)	tons (2000 lbs)	Ins.	lbs.	tons (2000 lbs)	tons (2000 lbs)	Ins.	lbs.	tons (2000 lbs)	tons (2000 lbs
¼	.5	2.09	.42	11/16	4.50	15.88	3.20	1⅛	11.83	42.52	8.50
5/16	.9	3.28	.65	¾	5.33	18.89	3.80	1 3/16	13.16	47.87	9.50
⅜	1.33	4.72	.95	13/16	6.16	22.17	4.45	1¼	14.50	52.49	10.50
7/16	1.75	6.42	1.25	⅞	7.16	25.72	5.15	1 5/16	16.00	57.87	11.45
½	2.33	8.40	1.70	15/16	8.16	29.58	5.90	1⅜	17.66	63.52	12.70
9/16	3.00	10.62	2.15	1	9.33	33.60	6.70	1 7/16	19.33	69.44	13.90
⅝	3.66	13.12	2.60	1 1/16	10.50	37.98	7.60	1½	21.16	75.60	15.15

N. B. In calculating the foregoing columns, the working load has been taken as equal to one-half the English Admiralty proof-test. For ordinary chain-slings, ⅔ of the above figures will be as high as safety demands.

NOTE.—An interesting example of the use of ropes and pulleys is furnished in landing the heavily armored shore ends of submarine-telegraph cables: Two light ropes are first brought ashore from the cable-laying ship. One is passed round a pulley firmly secured in the ground and spliced to the second. On an agreed signal being given, the ship, which is of course anchored, hauls on one end of the rope, and a heavier rope attached to the other end is drawn in to the shore. This also passes round the pulley and is taken back to the ship, but previous to its second end leaving the vessel the cable itself is attached to it. A number of barrels are then fixed at regular intervals between the vessel and the shore, and over these the cable passes, thus facilitating the hauling of the cable.

TABLE OF DIMENSIONS OF CAST-STEEL HOISTING ROPE.

(Roebling)

Composed of 6 strands of 19 wires each, with a hemp centre.

Diam. in Inches.	Girth in Inches.	Weight in lbs. per Foot Run.	Approximate Breaking Stress in Tons of 2,000 lbs.	Safe working load in lbs.	Minimum Diameter of Sheave in Inches.
$\frac{1}{4}$	$\frac{3}{4}$	0.10	2.4	950	6
$\frac{5}{16}$	1	0.15	3.4	1,350	8
$\frac{3}{8}$	$1\frac{1}{8}$	0.22	5.0	2,000	12
$\frac{7}{16}$	$1\frac{1}{4}$	0.30	6.8	2,700	15
$\frac{1}{2}$	$1\frac{1}{2}$	0.39	8.8	3,500	18
$\frac{7}{16}$	$1\frac{3}{4}$	0.50	11.0	4,400	21
$\frac{5}{8}$	2	0.62	13.6	5,450	27
$\frac{3}{4}$	$2\frac{1}{4}$	0.83	19.4	7,750	36
$\frac{7}{8}$	$2\frac{3}{4}$	1.20	26.0	10,400	42
1	3	1.58	34.0	13,600	48
$1\frac{1}{8}$	$3\frac{1}{2}$	2.00	42.0	16,800	54
$1\frac{1}{4}$	4	2.45	50.0	20,000	60
$1\frac{3}{8}$	$4\frac{1}{4}$	3.00	62.0	24,800	66
$1\frac{1}{2}$	$4\frac{3}{4}$	3.55	72.0	28,800	69
$1\frac{5}{8}$	5	4.15	84.0	33,600	75
$1\frac{3}{4}$	$5\frac{1}{2}$	4.85	96.0	38,400	87
2	$6\frac{1}{4}$	6.30	124.0	49,600	96
$2\frac{1}{4}$	$7\frac{1}{8}$	8.00	156.0	62,400	102
$2\frac{1}{2}$	$7\frac{7}{8}$	9.85	190.0	75,800	114
$2\frac{3}{4}$	$8\frac{5}{8}$	11.95	228.0	91,200	120

N. B. A factor of safety of FIVE has been assumed; in cases where the speed is high, the makers recommend EIGHT to TEN.

STEEL STRUCTURES.

Steel structures, especially those of a more or less temporary character, are usually fitted together, and erected in skeleton at the shop where they are made, so that the work of subsequent erection on the site is a simple matter. The rigging and the scaffolding necessary for the erection are, perhaps, the most important considerations, and will be dealt with under their respective heads. Whatever of riveting requires to be executed is effected either at the manufactory or on the ground. The connecting up of the various members being done with bolts, the tools used are few and simple.

Two points must be seriously impressed upon the erector. *First*, to study the plans and blue-prints carefully and often; to keep them arranged for easy reference, the particular drawing in use being pinned out on a board at a convenient spot. *Second*, to watch the *erection marks* and *numbering* of the various details with minute care, in order that the proper part may be fitted into the place destined for it, and none other.

The usual method followed for *erection marks* is to designate each similar division of the structure with one of the letters of the alphabet; thus each roof-truss of a building, together with its supporting pillars, will be lettered A, B or C, etc.; these letters showing on the blue-print, and also stencilled on the ironwork. The individual details of each member will be further figured 1, 2, 3, or 4 on the blue-print and on the member. Thus, if the

STEEL STRUCTURES.

king-post of the roof-truss be marked 7 on the drawing, and a piece of iron is found bearing the mark C 7, it will at once be identified as the king-post of the third truss.

Longitudinal members are marked with a number according to their position, and with letters to show between what sections they have to go. An angle bar is discovered with the mark B 10 C, and is at once seen to be purlin No. 10 to go between trusses B and C, the letters toward that particular truss. When plated structures, such as tanks, gas-holders and chimneys are temporarily erected, it is the customary practice to paint white lines vertically on the whole structure, with a letter for the course or strake, and a number for the plate. Thus it will be necessary first to fit in place the plate bearing the white line, so that the rivet holes coincide, and work right and left from it.

Many parts of a structure are made to template, and thus are interchangeable, but it is as well always to spend a little time in seeing that the right parts go together, as the drilling of girders, etc., is not usually so careful as that practiced in up-to-date boiler shops,

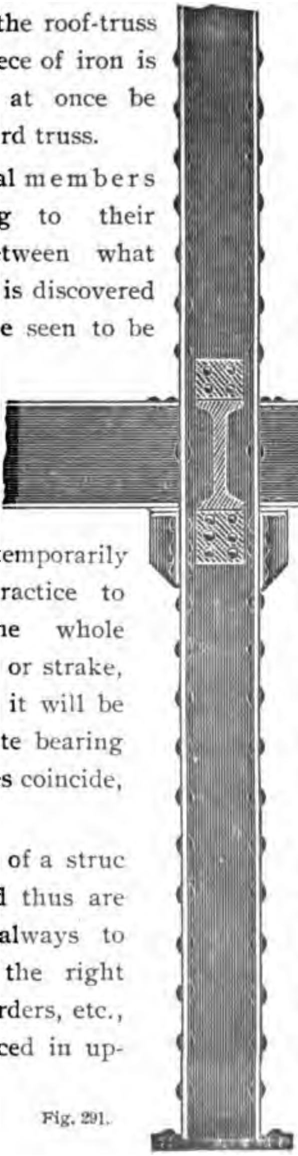
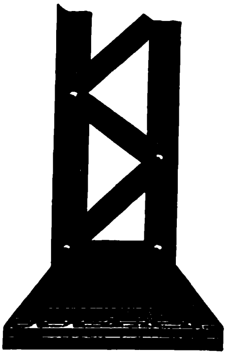


Fig. 291.

despite spacing drills, multiple punches and the like. It is, also, frequently to be noticed that where two or three plates come together, the corners have been tapered down subsequent to the drilling or punching of the holes, and "half-moons" are of frequent occurrence. This rough style of work requires careful manipulation, and fairing of the holes, and reaming followed by the use of a larger rivet is often to be recommended.



Care should be exercised in slinging any girder, so that its ends come in the proper direction; the channel irons should also be observed to see that they face the right way. Brackets and knee-pieces should be examined for marks, and, if their location is doubtful, should be tried on to their connecting pieces to see that the holes are fair. It is frequently necessary to do some drilling with these last.

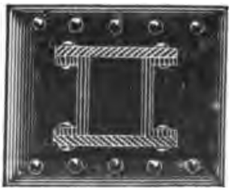


Fig. 222.

In bolting up connecting pieces, the boilermaker's spanner or fork wrench, Fig. 163, is most useful; the pointed tail or stalk is used as a "podger" to make the first connection as the new part is slung into place, and a little manœuvring fairs the holes so that one or two bolts can be entered.

In this connection, stress must be laid upon two points in dealing with bolting up structures:—(1) Never put a finger into a bolt hole to feel if the two pieces are fair; many a man has lost his finger by so doing when the girders have swung a little. (2) Do not tighten a single bolt in a joint until *all* are in, as occasional working of the parts is necessary to enter some of the bolts.

STEEL STRUCTURES.

Bolts should be long enough to give a full nut, in fact it is advisable that they protrude two threads through the nut. All nuts should be gone around two or three times to be certain that they are tight, and wherever much shaking of the ironwork is to be apprehended, the bolt-ends should be clenched over.

In riveting, an abundance of service (temporary) bolts should be put in, so that the different pieces of iron are drawn tightly together and the holes held fair. A certain amount of drifting, or at least, manœuvring with "podgers" and spanner-ends must be expected, and all holes should be fair before starting to rivet, as the practice of drifting after some rivets have been set is detrimental to the holding power of those rivets not yet cooled.

The rivets should be well bucked or hammered to fill the holes before proceeding to form the point, as, if the hole be not well plugged, the rivet will not stand its calculated strain. Snap, otherwise known as cup or hemispherical, heads and points are the best for this class of work, as the hole is well filled with smashing the rivet down, and a few blows of the flogging hammer on the set form a shapely point with good holding power, and serve to draw the plates well together.

Some typical illustrations of iron and steel framing follow, not so much as actual examples as ideal arrangements showing the usual practice in connecting details.

Fig. 291 shows the methods of connecting horizontal girders to a H-section pillar either by angle iron knees above and below, or below simply. It is frequently found necessary to provide vertical angle brackets, bolting each side of the web of the horizontal

STEEL STRUCTURES.

member, and thence on the cheek or flange of the upright girder, so as to stiffen the connection against lateral strain.

Pillars or posts are frequently constructed of *channel bars*, especially in those more or less temporary structures where a steel skeleton is covered with corrugated iron. A substantial pillar for a heavy structure is built up as Fig. 292, where two channel irons are riveted back to back with a latticing of steel tie plates. The bottoms of the channel bars are riveted to bracket web plates which form large angles and afford suitable transmission of stresses to the square base.

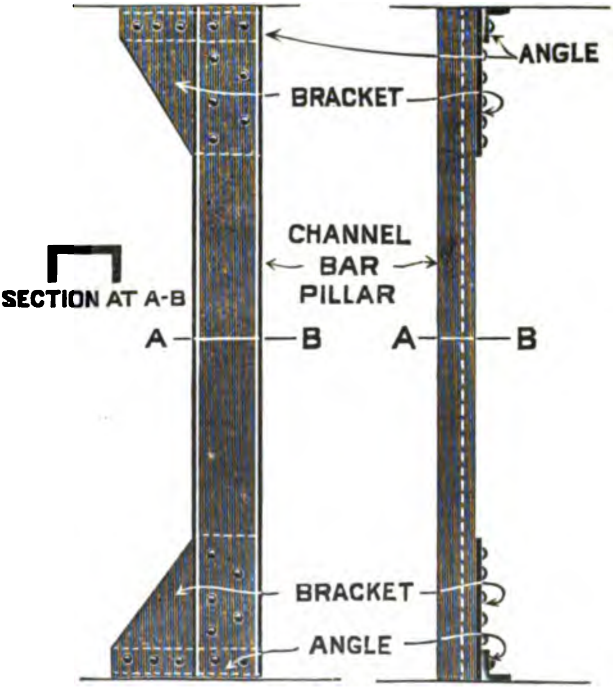


Fig. 293.

STEEL STRUCTURES.

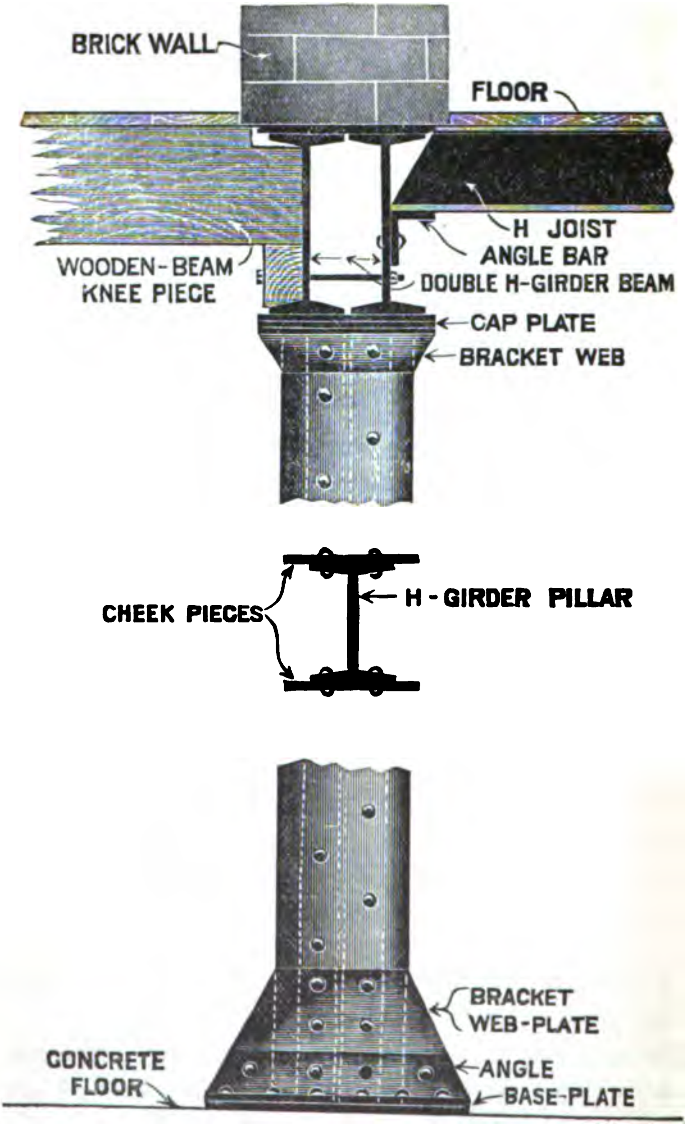


Fig. 294.

STEEL STRUCTURES.

Another method of connecting channel bar struts is shown in Fig. 293. The large brackets, stiffened at their edges by angle bars, support both the pillar and the floor which it stays, transmitting stresses equally over a large area. This section is much easier to make connections with than the H-girder, as will be readily understood from comparison of the illustrations.

In the engraving Fig. 294, a variety of constructions are shown together for purposes of comparison. The main pillar is built up of a large H-section with *cheek-plates* riveted on each side, increasing the size and strength of the flange. Large bracket pieces and angles distribute the stresses of the pillar evenly between it and the other members at base and capital. The main beam, which the pillar serves to support, is a compound box girder built up of two very deep I-beams with flange plates top and bottom.

A brick-and-a-half wall is shown as supported by this beam, and the details for connecting transverse floor beams to it are clearly exhibited. The I-beam joist is supported on angle bar brackets, while the wooden beam on the left of the engraving is supported by a knee-piece or furring bolted to the longitudinal beam.

Steel or iron roofs are increasingly common; and the erector may frequently find himself called upon to put one up if he pursues his avocation outside populous centres. Fig. 295 gives a good idea of the general arrangement of a roof principal, together with enlarged views of details of connections.

In this instance, the compression members are simply flat steel bars, bolted or riveted together, with thimbles over the bolts or rivets to maintain the bars at the proper distance apart. The ten-

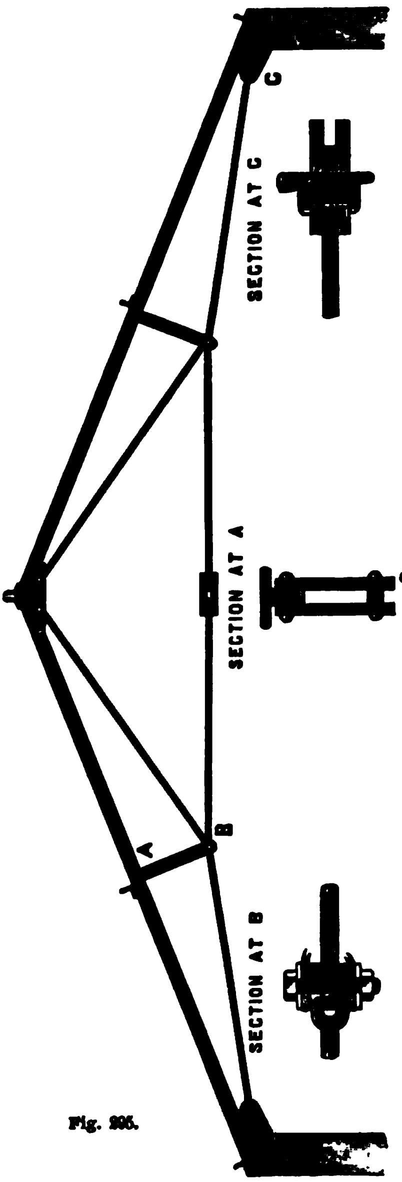


Fig. 205.

sion rods are simply eye bars, pinned at one end to the ridge plates, and at the other to the compound joint, marked B in the drawing. The tie-rods are fixed into the wall-brackets with gib and cotter as at C, while proper tension is obtained by means of the turn-buckle, screwed right and left hand.

The small angles noticed on top of the rafters are brackets to which the purlins are bolted. These purlins are of angle or tee bars, the former being used for a corrugated iron roof, hook bolts serving to fasten the sheets on to the angle bar. Purlins of T-section are used when board or felt coverings are used.

It may not be superfluous to say that with corrugated iron sheets, the bolt holes should be punched through from what is to be the *under-side* of the sheet, and through that part of the corrugation

ROOF DETAILS.

which will be the ridge, when the sheet is in position, and not the valley. The burr around the punched hole will prevent the entrance of rain-water, and its position on the ridge will ensure that the rain will not flow on to it from other parts of the roof. A strand of flax dipped in white-lead paint and wound around the hook-bolt under the galvanized washer makes assurance doubly sure.

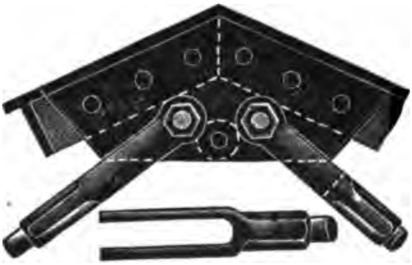


Fig. 226.

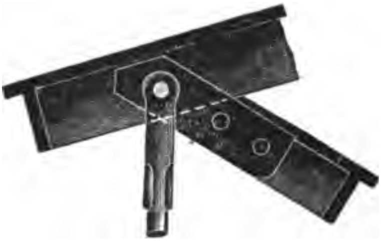


Fig. 227.

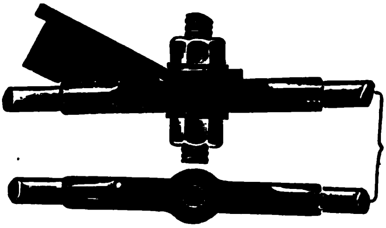


Fig. 228.

Other details of typical roofs are given in accompanying illustrations.

STEEL AND IRON ROOFS.

Fig. 296 shows the connection of *tension bars* to the ridge plate, such bars being forged with a double-eye or fork at each end. In this case the ridge plate is a single web, and a boss will be forged upon the tie bar in a vertical plane.

Fig. 297 represents the connections at other points of another type of roof truss; the tension bars being forged with a double-eye at the top, while they are threaded at the lower end for fastening on to the tie bar, with a nut each side of the boss, which, for the purpose of the compound joint, is made in a horizontal plane. The compression members of this roof truss are tee-bars, fished on to the rafters with splice-bars as in Fig. 297, and bolted on to the tie rod as shown in Fig. 298, the web of the T being cut away and the flange or top table bent in the correct angle for the connection. The different views make these points clear.

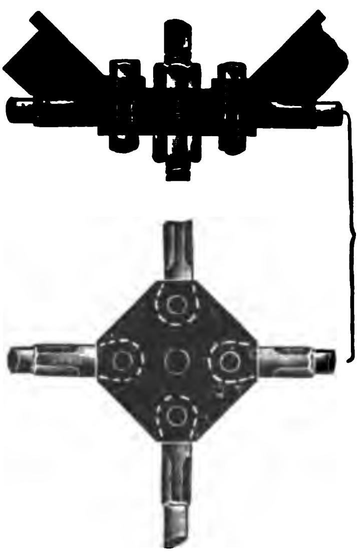


Fig. 299.

Fig. 299 shows a distinctly compound joint, applicable to octagonal roofs, or where longitudinal trussing is necessary as well as lateral. The four tie-bars have single-eyes on their ends, and are united by top and bottom covering plates. The reader will notice how economy of fastenings has been achieved in this particular joint; the lock-nuts on the tension-rod, bind the covering plates together, and the bolt which connects the tie-bar with the joint, also fastens the adjacent compression-bar to it; thus exclusive of the central rod, four bolts fasten ten pieces securely together.

Roof principals, or trusses, are connected to the pillars, of H or channel section, which support them through the agency of angle brackets. Fig. 300 is a side view of a simple connection of this nature, and shows plainly the usual manner of attaching the forked end of the tie-bar. Fig. 301 is an elevation and Fig. 302 a cross section of an angle bracket as used where the roof is built altogether of tees and angles.

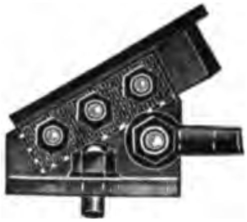


Fig. 300.

Many devices are used by constructors to facilitate the manufacture and consequently cheapen the price of roof details, and cheapness of cost as well as speed of erection is often attained by using modifications of the covering plate joint, Fig. 299, instead of the relatively complicated connections shown elsewhere. Single-eyes replace costly fork ends in rods; angle or T-bars are simply cut on the web and bolted up without forging or bending, and the number of bolts saved is very great.

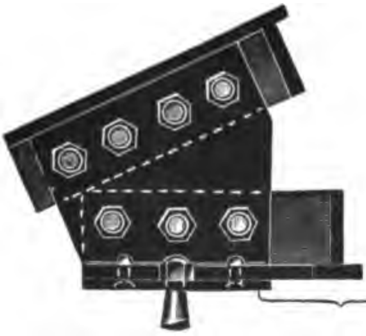


Fig. 301.

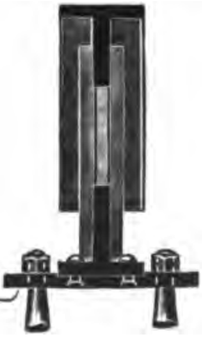


Fig. 302.

CONVENTIONAL SIGNS.

When a long and slender object has to be drawn, it often happens that, if it should be drawn to a sufficiently large scale, or one on which details would be intelligible, it would extend beyond the space available. In such a case, the middle part of the object (where it is of uniform section) is broken out and the ends pushed together, such breaking away for convenience being clearly indicated by irregular edges as of a fracture.

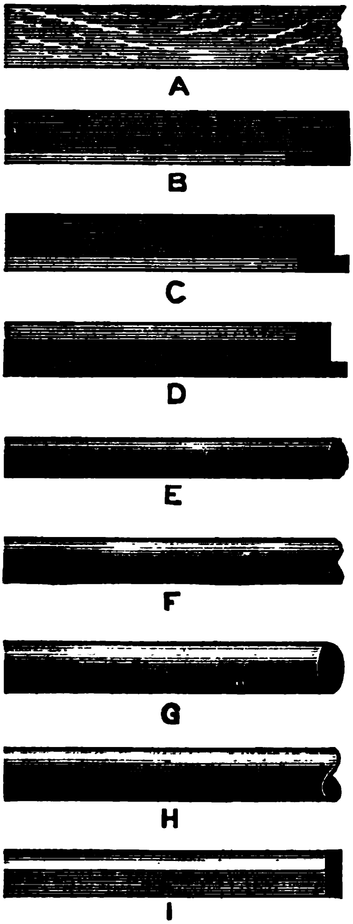


Fig. 303.

A familiar instance of this method of procedure is shown in the working drawing of a piston-rod, where the taper and thread fastening it to the piston, and the taper and cotter hole for connecting to the cross-head are shown full-size on the sheet, the parallel portion of the rod, which is of uniform section throughout, is broken away, to prevent the drawing from being of an unwieldy size, the proper length being indicated by the dimension lines.

Generally this break is made to indicate the section of the piece, and thus save a second view, as in B, C, D, E, G and I on Fig. 303. A break in wood is

SYMBOLS FOR RIVETING.

indicated by A, cylindrical objects usually are represented as at E or F, and pipes as G or H.

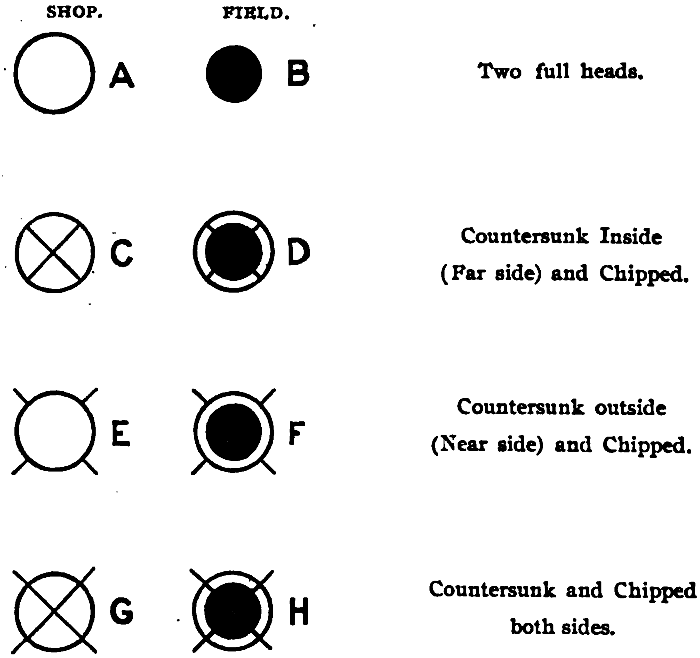

SHOP.
FIELD.
A
B
Two full heads.
C
D
Countersunk Inside (Far side) and Chipped.
E
F
Countersunk outside (Near side) and Chipped.
G
H
Countersunk and Chipped both sides.

Fig. 804.

In connection with the building of steel structures, it is often desirable to execute some of the riveting in the shop or yard at the time the plates, girders, etc., are made. The remainder of the rivets require to be put in at the site of erection, or ***in the field***, as it is termed.

SYMBOLS FOR RIVETING.

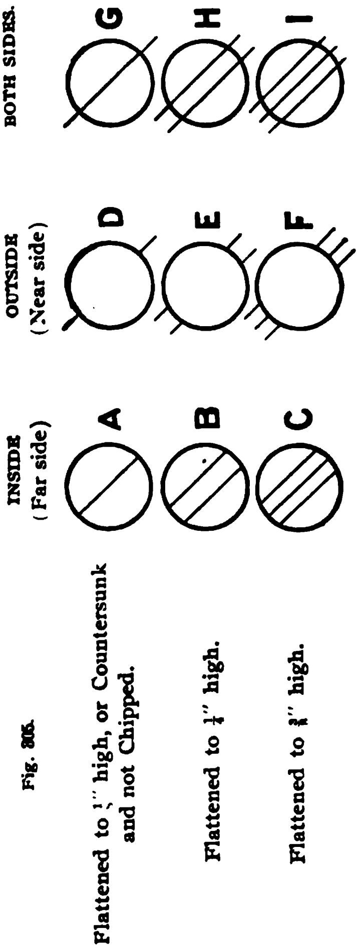

BOTH SIDES.
OUTSIDE (Near side)
INSIDE (Far side)
G
H
I
D
E
F
A
B
C
Flattened to $\frac{1}{8}''$ high, or Countersunk and not Chipped.
Flattened to $\frac{1}{4}''$ high.
Flattened to $\frac{3}{8}''$ high.

Fig. 305.

This division of work may cause confusion, or entail a multiplicity of drawings, and in order to avoid these faults, the system of conventional signs illustrated in Figs. 304–305 has been devised by F. C. Osborn, C. E.

The foundation of the system consists of a *blackened circle* (represented by a white spot in a blue-print) for a rivet which has to be set in the field, a *diagonal stroke* to indicate a flattened head, and a *diagonal cross* for the purpose of showing those rivets which require to be countersunk.

If the cross or stroke be *within* the circle, it denotes that the special head must be put on the side *away* from the observer as he looks at the drawing, or on the side represented by the back of the paper. When the distinguishing marks are placed *outside* the circle, the desired point must be on the side represented by the *front* of the paper.

Any other combination of shop and field work, or any desired type of head, may readily be indicated by these signs.

BLACKSMITHING.

A blacksmith was formerly a smith who worked in *black metal* or iron, as distinguished from a white smith, who worked in *white metal* or tin.

The history of the blacksmith is a long and most honorable one. The smith's fire illumines the early pages of history, and the ring of his anvil is one of the remotest sounds we hear. The smith made the first swords and shields and coats-of-mail even before he made the plowshare. The weapons of war were made by him before the simplest machine, but the machine was his later product, and *the machine is one of his lineal descendants.* The same man in the beginning worked the metals in both the plastic and the liquid states, so that *the foundryman* was originally a smith.

The field of the blacksmith has been growing with the growth of the country and the increase of inventions: there are a thousand and one things that he is called upon to make, and his field will widen with the multiplication of industries. The machine works of the time embrace a trio of shops—the machine shop, the foundry and the blacksmith shop—and in the case of a steam-engine works there is also the boiler shop, which is another distinct outgrowth from the "smithy."

Blacksmiths' tools and various processes connected with the shaping of iron and steel have been described on pages 145–148 with illustrations. To these the reader is referred.

NOTE.—Originally the term smith was applied to anyone who made anything. The large family of Smiths are honorably descended from people who in early times had accomplished something notable.

BLACKSMITHING.

Welding is the art or process of uniting two pieces of iron or steel while in a partially melted state. Several kinds of welding are used, taking their names from the shape in which the ends of the pieces are prepared before the operation. All methods of preparation are due to the necessity of allowing more metal at the point of union to permit of the hammering needed to coalesce the fibres of the parts.

Scarf Weld.—This is, perhaps, the commonest mode of procedure. The ends are staved up by bumping on the anvil or a heavy block, and then faced to an acute angle, first by means of a fullering tool (Fig. 144), and next with a flatter (Fig. 146); finally assuming the appearance seen in Fig. 306. The two portions are put in the fire together, drawn out when at a good *white* heat, and superimposed upon the anvil, two men holding the ends with tongs. A few light blows with the hand hammer cause the pieces to adhere and the work of union is completed with the sledge-hammer. A finish is put upon the work, if round, as illustrated, by application of the swages (Figs. 149-150).

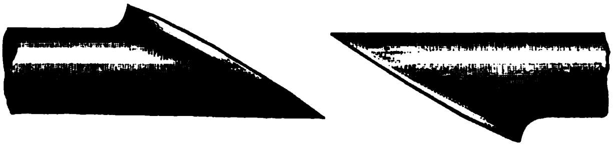


Fig. 306.

Butt Weld.—This has to be resorted to when scarfing is difficult on account of the shape of the pieces dealt with, as in uniting a bar to the surface of a plate or to a large ball. The end of the bar is staved or upset as before, but no scarfing is attempted, only to give the end a slightly rounding or convex shape. The object of this is to permit scale or oxide to escape from the sides of the weld. When the two portions are at the proper heat, they must be forced together at the desired point by striking on their ends until incorporation has taken place. A butt weld in a bar is completed in similar manner to a scarfed one; but when a bar is joined to a plate, the finishing must be effected with a fuller, the necessity for the curved fuller (Fig. 145) now being apparent.

Vee Weld.—This is diversely known as bird-mouth weld or tongue joint, and consists in opening one end of one bar to form a V, and drawing the other bar down to a taper to fit within it, as seen at A A in Fig. 307. This is, perhaps, better for heavy work than the simple scarf, and may make a more reliable connection. The procedure after shaping the ends is as before.

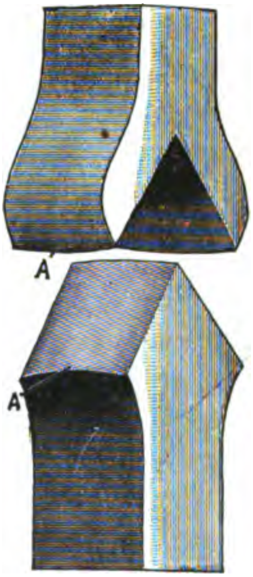


Fig. 307.

Glut Weld.—For repair jobs, some very difficult problems are occasionally met with, as the length of the repaired piece must remain the same, and scarfing or butt welding is clearly impracticable, as either method would entail shortening. Supposing a square eye-bar or pitman to have carried away, the length between centres must, evidently, remain unchanged, and the first process is to make a trammel to gauge that dimension. The ends of each piece are then staved up into a blunt taper form or double scarf, and when ready for welding are brought point to point; wedges or small pieces of wrought-iron bar, also at a white heat, being laid in the valley and the whole welded up. Fig. 308 gives a representation of the manner in which the various pieces are brought together.

The continual use of the *trammel* or measure will keep the piece of the desired length. If the break be large, several wedges or filling pieces may have to be inserted, making the job a tedious one, but likely to be most satisfactory.

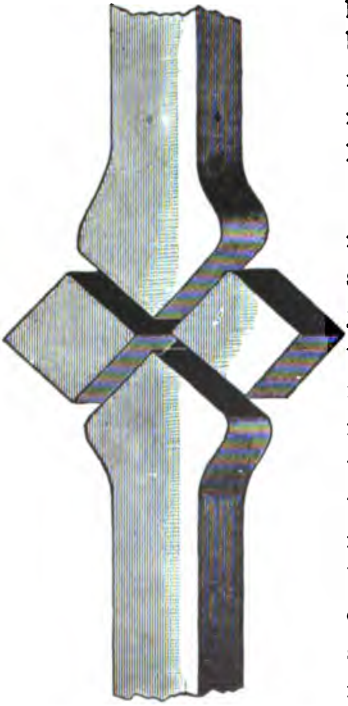


Fig. 308.

Welding Steel.—When it becomes necessary to provide a tool with a steel point, as with quarrymen's jumpers or drill-bits for artesian wells, the vee weld comes into requisition, the butt-weld being inadmissible. The steel end is worked down to a fairly long taper, while the mouth is formed in the iron shank. The steel is brought to a *slight white heat*, care being taken not to overheat it, and sprinkled with flux from an iron spoon; when the flux has melted, some more powder is sprinkled upon the joint, and the operation of welding is at once proceeded with. The nearer the steel approaches to wrought iron in its proportion of carbon, the easier it will be to weld; on the contrary, as the hardness of the temper increases, so does the difficulty of welding.

FLUXES.

Fluxes.—A flux is a substance, as borax, that promotes the fusing of metals; as in soldering tinware rosin is commonly used as a *flux;* the flux forms a skin on the surface of the heated metal and protects it from the attacks of the oxygen in the atmosphere. The light blows given in the first stage of welding expel both flux and scale from the joint. In practical operation the smith often uses a little fine sand to sprinkle over the portions of the work he heats, especially when welding scarf joints in wrought iron; ordinary borax is often applied for the same purpose, especially with mild steel.

A flux used for uniting steel with wrought iron consists of six parts of powdered limestone mixed with one of sulphur, the ends of the two portions being dipped in the mixture four or five times whilst heating, before actually welding.

When uniting steel with steel, the following is recommended: borax, 4 oz.; washing potash, 4 oz.; and a small quantity of ground glass. All should be melted together and pulverized when cold.

Several authorities give the following recipe for use with steel, and it will repay for the trouble incurred in its manufacture: Take by weight: borax, 14 oz.; sal-ammoniac, 2 oz.; prussiate of potash, 2 oz.; unrusted wrought-iron filings, 1 oz. The whole is ground up with a pestle and mortar and then placed in a sheet-iron pot or crucible (an old pail will do), together with sufficient water to make a thick paste. The vessel is boiled over a moderate wood fire, the contents being constantly stirred. A mass like pumice stone, streaked with grey and green, results, which is allowed to harden, is cooled, and once more pulverized, when it is ready for use.

WELDING STEEL.

In welding *cast or tool steel* the following points deserve careful study :—

(1) Do not use coal, as it may contain sulphur, but use coke, charcoal, or what is known as breeze, namely, washed and sorted cinders of partly burnt coal.

(2) Keep the cast steel covered up while heating, and bring it to its heat as quickly as possible, with a view to prevent oxidization.

(3) As cast steel requires but a low welding heat, it must not be made too hot; in that case, it will either burn or break into pieces while being hammered.

(4) Apply some flux (made as previously described) before putting the work into the fire, to protect the surface from the formation of scale or oxide, and add more at discretion, preferably as mentioned in a previous paragraph.

(5) When welding steel and iron, the iron must be hotter than the steel.

(6) Clean off both surfaces with a short besom or hand broom before putting the parts together, and sprinkle flux at the last moment.

(7) Strike light blows and quick at first, and then increase to heavy blows at completion.

Temper of Steel.—This term, as used by steelmakers, denotes the amount of carbon which is present in steel, and its consequent hardness. The chief classifications are enumerated below :

Razor Temper.—This has 1½ per cent. of carbon, and is so easily overheated that its manipulation can only be entrusted to a person accustomed to work with it. When properly treated it will do twice the work of ordinary tool steel in turning chilled rolls, etc.

VARIETIES OF TEMPER IN STEEL.

Saw-file Temper.—Contains 1⅜ per cent. of carbon, and demands the same careful treatment as the preceding. Though it will stand the fire better, it must not be heated above a cherry-red.

Tool Temper.—This possesses 1¼ per cent. of carbon, and is the quality recommended for machine tools. This steel may be welded, but the operation demands skill and experience.

Spindle Temper.—With 1⅛ per cent. of carbon, this furnishes the best results for very large turning tools, milling cutters, taps and screwing tackle. Considerable care is required in welding it, the flux previously referred to (composed of borax, sal-ammoniac and yellow prussiate of potash) having been used with success.

Chisel Temper.—This useful temper has 1 per cent. of carbon, and possesses great toughness in its soft state. It hardens at a low heat and may be welded without difficulty, being thus adapted for providing a cutting tip to tools and instruments which have to stand blows and jarring.

Set Temper.—Containing ⅞ of 1 per cent. of carbon, this quality is well adapted for tools such as drifts, cold sets, etc., which have to stand their principal punishment on the unhardened parts. Can be welded easily by a toolsmith.

Die Temper.—This has only ¾ of 1 per cent. of carbon, and is the most suitable temper for such tools as dies for presses, rivet-snaps, etc., where hardness is required only upon the surface, and the capacity of withstanding great pressure is of the utmost importance. This quality welds with freedom.

TABLE OF COLORS OF TEMPERED STEEL.

In this case tempering relates to the degree of hardness obtained by plunging the steel when heated to a cherry red, into cold water.

COLOR.	TEMPERATURE F.	CLASS OF TOOLS FOR WHICH USED.
VERY PALE YELLOW...	430°	Scrapers for brass. Light turning tools. Hammer faces.
LIGHT STRAW.........	450°	Planing tools. Drills.
MEDIUM STRAW.......	460°	Milling cutters.
FULL STRAW..........	470°	Boring cutters. Screwing dies.
DARK YELLOW........	490°	Taps. Chasing combs. Punches and dies.
YELLOW BROWN.......	500°	Reamers. Gouges. Plane irons.
PURPLE ORANGE......	520°	Twist drills. Flat drills for brass.
LIGHT PURPLE........	530°	Augers. Chipping chisels for steel. Axes and adzes.
DARK PURPLE.........	550°	Chipping chisels for cast iron. Firmer chisels. Cold sets.
DARK BLUE...........	570°	Springs. Circular saws for metal. Screw drivers.
MIDDLE BLUE.........	590°	
LIGHT BLUE..........	610°	Saws for wood.
GREENISH PALE BLUE.	630°	

HARDENING AND TEMPERING.

Tempering is the giving any required degree of hardness to a piece of steel; properly speaking, there are two distinct processes implied in the term, one being *hardening*, in which the steel is heated to a cherry red, corresponding to about 1,650° Fahr., and plunged into cold water, making the steel hard enough to scratch glass. Next follows the second process of *tempering*, which must be performed to "draw the temper" to the proper degree.

In this, the steel *is reheated after hardening* until it attains the proper color, corresponding to its temperature, as seen in the preceding table. The steel is then plunged into water for the second and final time. The colors upon the surface of the steel are due to films of oxide of varying thickness, formed by the action of the air upon the metal. *When the quenching medium is water, the preliminary process of hardening must be carried out*, or else the act of tempering would be without effect.

The heating is best carried out in a clear coke or charcoal fire, or, if the articles are small, they may be placed within a D-shaped muffle, or shallow sheet-iron box placed over the fire, to avoid formation of scale, unequal heating or discoloration of polished work; tool steel should be protected from the blast or draughts while heating or annealing, and the heat should be as uniform as possible over the whole of the article. This is effected by moving it about through the fire, or, when a muffle is used, in turning the pieces around and over with the tongs. If steel is exposed to too great a heat it becomes "burnt," and its quality is deteriorated. In view of this, until the quality of any particular steel becomes well known, it is wise to be even over-cautious in the amount of heat applied. At the worst, the piece need only be re-hardened at a high temperature, whereas, if overheated, its quality will be permanently injured. Tool steel showing a bright and granular fracture has probably been overheated ; if not, it will be dark and even.

In view of the many reliable circumstances met with in tempering, it is frequently advisable to use a flux or bath in which the tool can be uniformly heated. The Waltham Watch Co. heat their hair-springs in molten glass. Pratt & Whitney use an equal mixture of potassium cyanide and common salt for heating taps, as also do the Morse Twist Drill Co. for many of their specialities.

When an article is heated in a bath of molten lead, the surface of the latter being strewn with powdered charcoal to prevent oxidation, and then tempered, the interior will be softer than the outside ; this result is desirable for taps, reamers, etc.

The *cooling medium* used, it is well to bear in mind, influences the hardness of the temper ; with *oil*, a species of tempering can take place *without preliminary hardening*, which is especially useful in dealing with large pieces, as not only does it harden the material, but may increase its strength while the uniformity of the process is assured. The articles are heated all over to a dull red heat, and then immersed in the oil, generally olive oil. Only one degree of hardness, that of a very dark straw color, can be obtained in this way ; but there is a more equable temper imparted for the same color than with water quenching, on account of slower cooling. *Plain water* makes the best bath for all general purposes; the most favorable results have been attained with it at a temperature of about 40° Fahrenheit. Many tool smiths prefer to use the same water over and over again instead of changing it ; but it is as well to keep it in circulation in the bath. A good plan is to admit a copious supply through a perforated false bottom, the excess of heated water escaping by a waste pipe near the top.

An oily film on the surface of the water will often save small articles from cracking, and will also take the chill off the water. *First hardening in water and then tempering in oil gives a superior softness to tools.*

For harder materials *brine* may be used, composed of fresh water with enough salt added to float an egg, or half a pint of salt to one gallon of soft water. A *mercury* bath is supposed by many to make the hardest grade of steel, but if the very hardest possible point is wanted on a steel tool, its point should be brought to a cherry red and then be thrust into a solid block of *lead* until cooled.

In tempering tools, it is always advisable that the parts should be ground or machined to a surface beforehand, as the natural skin of the metal gives false colors.

Unequal heating is as much responsible for the cracking of milling cutters, pipe-cutter-wheels, etc., as unequal cooling, and to avoid this the process of heating in a bath of molten lead maintained at a high temperature has been successfully tried. When dipping these articles it is wise to sling them from a wire threaded through the hole and having its ends twisted over a small rod to carry or suspend it, the hole being filled with fire clay. This prevents cracking at the central hole.

Toothed drifts for cutting out long narrow holes should be tempered all over to a purple blue; those of stouter proportions can be made of a brown purple.

Taps require to be softer on the shank than at the teeth to avoid breaking off in use. A neat way of effecting this is to procure a piece of iron tube, just a shade larger than the tap, and a pair of round bit tongs as shown in Fig 140. After the tool is made and polished it is first hardened, and then the temper is lowered in the following manner: The preliminary heating being done in a muffle or on a plate, to avoid discoloration, the tongs, which have been made bright red in the fire, are used to grip the tap by the shank, to bring the color down.

Meanwhile the piece of pipe has been brought to a *dull red.* As soon as the first signs of straw color appear on the shank, from the heat of the tongs, the tap is thrust into the tube up to the end of the threads. This keeps the color back on the screwed portion, and the shank will be dark blue by the time the threads have reached dark straw, when the whole can be plunged into the water. It is, of course, necessary to employ long-nosed tongs, to heat the whole of the shank.

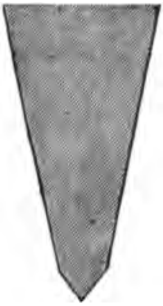
The countersink is used for enlarging orifices, such as are employed for rivet holes requiring to be flush or even with the surface of the riveted plate. In tempering these tools or any others having a pin or projection to serve as a guide in the hole, it is necessary that the pin or teat working in the hole should be much harder than the cutting edge. It is therefore customary, first to harden the tool fully, dipping it gradually into clean water to avoid cracking, and then lower the hardness to the requisite temper by heating the tool upon a bar of red-hot iron.

As soon as the pale straw color has come down to the pin, it must be kept in that state by directing a little stream of oil upon it, while the color "comes down" to the required shade on the main part of the tool, plunging it into clean water as soon as that stage has been reached.

TOOL DRESSING.

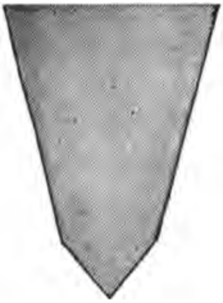
Tool dressing refers to, 1, the forging to shape, 2, hardening and tempering and 3, grinding; in the present connection, consideration need alone be given to those more likely to be used by the outside workman.

In dressing *chisels*, it is necessary to make a distinction between the uses to which the tool is to be put. A chisel for chipping requires to be at once light and hard, and the long tapered portion should be drawn down very thin, the sides forming an angle of 22° to 25.° The cutting bevel may be 80,° and should be ground accurately and sharply. It is advisable to give the tool a slight convex or rounding sweep on the point, so that the corners shall not dig in and break off. It is of prime importance to feel the chisel lying parallel with the work, and for this reason the flattened oval section of steel is sometimes preferred for chipping purposes, as the wider side gives a better guide to the hand. A section of the cutting edge of this type of chisel is exemplified in Fig. 309.



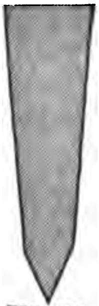
CHIPPING

Fig. 309.



BOLT CROPPING

Fig. 310.



HOT SET

Fig. 311.

TOOL DRESSING.

Other flat chisels require to be furnished for bolt cropping, cutting of bars and the like, and these in practice are much heavier and softer than for chipping. The long taper should be drawn down to an angle of 30° between the sides, with the bevel points forming another angle of 75,° or rather less than for chipping. In tempering, the tip only should be hardened; it is better to have the tool bend than break. These chisels present a sectional appearance, as seen in Fig. 310.

All rod chisels should be made entirely of tough steel and not, as often done, have an iron shank welded on; care being taken to harden half an inch of the point only, also to leave the head as soft as possible. Whenever the cutting end becomes too thick from hammering or grinding, it should be drawn down once more to the same angle as when first made. When such thinning has been done, it is advisable to cut a quarter of an inch off the point, as that may have been burnt, and minute cracks, invisible to the eye, most likely have been set up in the steel.

When a *hot set* is used for trimming forgings, etc., it is frequently welded on to the end of a bar, forming a sort of butcher's cleaver with a long handle. This style of chisel is known as a *trimmer*, and it is customary to make the width of the edge hollow or concave, so that it can be slid easily over the work. Hot sets and trimmers should be forged with a long

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NOTE.—As the hand is liable to perspire more freely when slashing off bolt-heads, etc., in an engine room or on a repair job, than in chipping work in a cool factory, that form of steel must be used which will afford the better grip, and for that reason, the writer prefers the flattened oval section for cropping chisels and cold rod chisels. If care be taken at the same time to make all chipping chisels of octagonal steel the annoyance will be saved of attempting to split a nut with a chisel which flies into pieces at the very first blow.

taper of about 12° between the sides, or even 10,° the facets of the point enclosing an angle of 40° to 50.°

The cutting angle of a hot set is set forth in Fig. 311, well showing the necessary keenness of the tool.

In forging drills, the point requires to be as thin as possible consistent with ample strength, and this will be found to be of approximately the following dimensions:—

TABLE.

DIAMETER OF DRILL.	THICKNESS AT POINT.	DIAMETER OF DRILL.	THICKNESS AT POINT.
$\frac{1}{8}$ inch.	$\frac{1}{64}$ inch.	$\frac{5}{8}$ inch	$\frac{1}{16}$ inch.
$\frac{1}{4}$ "	$\frac{1}{32}$ "	$\frac{3}{4}$ "	$\frac{1}{16}$ "
$\frac{3}{8}$ "	$\frac{3}{64}$ "	$\frac{7}{8}$ "	$\frac{5}{64}$ "
$\frac{1}{2}$ "	$\frac{1}{16}$ "	1 "	$\frac{3}{32}$ "

The thickness of the flat face must gradually increase until the full diameter of the drill shank is reached, *the thickness at the cutting corners being about double that given in the table for that at the extreme point.*

The angles of the facets, or bevel edges, demand some attention, as a certain amount of "backing off" is necessary. An angle corresponding to 5° is a fair amount, suitable for heavy work, but where there is less strain, as with brass and softer materials, the angle may be increased to 15°. Authorities vary as to the angle of the cutting edges with the axis, hence a mean must be taken. A drill in which the two cutting edges make an angle of 60° with its axis, or which enclose one of 120° between them, will serve for heavy work on cast iron and hard steel; the general run of practice authorizes an angle of 45°, which is found by laying the ordinary square across the end of the drill, as the two sides enclose a right angle.

Angles of 35° to 40° are advised for softer metals.

In view of the support afforded to the drill by the sides of the hole, it is advisable to make the vertical sides nearly parallel, leaving the clearance angle quite small, not more than 3°. Drills for important holes are frequently turned up in the lathe to make them true, and left parallel for some distance on the sides to act as a steadier.

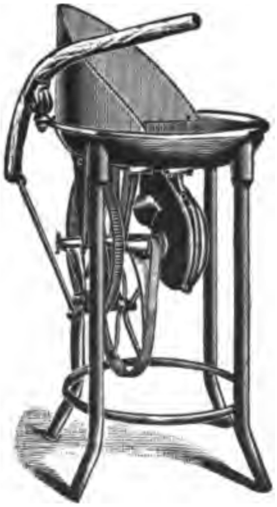

Fig. 812.

By bending the edges of a drill forward, a *lip-drill* is formed which has superior cutting properties to the ordinary drill, the angle of the two faces being more acute, while the cutting edge is well supported by metal behind it.

A *forge* is an open fireplace or hearth with forced draft for heating iron, steel, etc. Forges are named from their construction, as *double-blast*-forge, *fan*-forge, *hooded*-forge (having a hood to catch the smoke), *bench*-forge for use on a bench.

The small circular forge shown in Fig. 312 with a 20-inch pan, owing to its portability, can be carried into the field for such purposes as tool dressing and the like. The best type of portable forge will take apart into three pieces by the disconnection of a few wing-nuts; fan, pan and legs, packing separately for transportation.

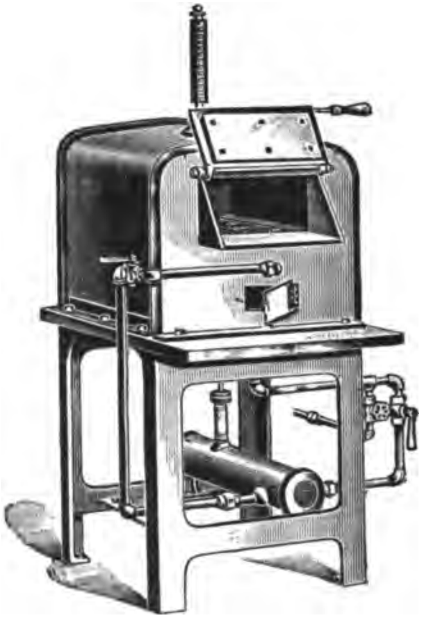

Fig. 313.

Wherever more than rivet heating or chisel dressing is intended, it is advisable to use a large square pan forge, of a more substantial type. As bellows are undesirable, a forge 28″ x 40″ may be recommended with a fourteen-inch fan; the latter will be driven by means of a lever through a sort of sun-and-planet motion, or by the intervention of a chain like the gear chain of a bicycle, from a large sprocket wheel. In either case the final multiplying power is transmitted to the fan pulley by a belt; as a plain flat leather or textile one.

It is claimed, with a forge of these dimensions, that a welding heat can be obtained on a three-inch bar in five minutes, and on four-inch iron in ten minutes. With the addition of a *bosh* or water tank this forge will weigh 300 lbs.

A furnace is a structure in which to make and maintain a fire. The figure 313 shows *a small portable gas furnace*. It consists of a fire-clay body into which project burners of the Bunsen type, producing a non-luminous flame of very great heating power. In both shop and erecting, this furnace is very useful for tempering tools, annealing, etc.

The tuyere is one of the most important parts of a furnace or forge; no fire can be made to burn without air and it is through its discharge opening that air is brought in contact with the fire, hence care should be exercised in keeping the pipe and nozzle clean from ash and coke.

The best *fuel* for use on the hearth or forge is *coke*, or else *breeze*, which is coal previously carbonized in a separate oven, then washed and sifted. Raw coal causes viscid and sulphurous scoriæ to cling to the surface of the iron or steel, rendering it brittle, as well as destroying the adhesive quality possessed by those metals when at a welding heat. Notches should not be made in the scarfs of two pieces about to be welded, as they form a lodgment for cinders or scoriæ. Neither should the practice be permitted of throwing fresh fuel into a hollow fire upon the hot iron just as the heat is coming out.

HACK AND BAND SAWS.

A hack-saw is a close tooth, metal-cutting frame saw with a moderate set. It is an exceeding useful implement for cutting almost all metals, from the very hard to the softest, such as iron, steel, brass, copper, bronze, sheet metal and tubing—in fact anything that a file will cut.

These machines are most useful as hand tools, filling a demand for a proper instrument to cut irregular sizes, curves, castings and irregular fittings in iron construction work.

Band-saws are power machines, also designed for cutting metals, and are operated in the same manner as a band-saw made for cutting wood. In these saws the teeth are hard, harder than the metal to be cut, but the back of the blade is soft, being made on the flexible-back principle, and hardened only to the base of the teeth, the back remaining soft, to insure them against cracking or breaking while in operation ; the teeth have the necessary set to give the saw proper clearance.

THERMIT WELDING.

As a method for welding, thermit begins where the blacksmith's forge ends.

Thermit is a granular mixture of aluminum and iron oxide *in exact chemical proportions ;* so that a perfect union may ensue on combustion and nothing but alumina and pure iron remain as products.

The thermit compound is a grayish black powder, very like coarse gunpowder in appearance. When it is desired to obtain molten iron either in its pure state or for welding purposes the aluminum powder and iron oxide, or iron rust, are placed in a crucible made of magnesia or other suitable material having high heat-resisting qualities.

THERMIT WELDING.

The thermit is ignited by a special powder which may be started by a match, thus causing a local heat of sufficient intensity to ignite the thermit, whose ingredients now combine and cause the enormous temperature of 5,400° Fahr. by their combustion. The reaction producing this result takes place in less than one minute, without regard to the quantity of thermit used.

Certain welds formerly made by the aid of electricity, as the joining of rails, are now executed by this simpler and cheaper process. Liquid thermit is poured from the crucible on the parts to be welded, as in joining iron and steel pipes. The latter are connected by clamps with a mould around the point of union; the use of stretching-screws upsets the ends and completes the weld. Broken cast-iron pieces are patched by pouring a little molten cast iron into the mould surrounding the break, filling up with thermit and igniting as previously described.

There are two ways of using thermit practically. 1, The iron may be run before the slag, which collects on the top, by tapping the crucible at the bottom, thus obtaining the highest possible temperature; 2, the crucible may be tapped from the top, running off the slag first, which, meeting the parts to be welded, coats them with a resistant film. This prevents close contact of the molten iron and reduces the temperature to a reasonable welding heat between the surfaces of the union. This method is adapted for iron or steel pipes and gives a clean joint after the removal of slag.

LEATHER AND OTHER BELTINGS.

A belt is a continuous strap or band for transmitting power from one wheel to another. Belts collectively, or the materials from which they are made, are termed belting, as leather belting—that made from the tanned skin of animals—and cotton belting—that made from the fibre of the cotton plant.

Many belts are named from their manner of using; as driving-belt, cross-belt; other belts derive their name from their arrangement of construction, as endless belt, wire belt, etc.

Leather belting, on account of its extra adaptation to various uses, claims and receives the first attention of the user. The best leather is that which comes from the back of the animal, from the rump to the shoulder; this portion of the hide is termed the *butt*. The leather is thicker and stiffer along the line of the back-bone, becoming more elastic farther away from it. To procure equal stretching of both edges of a belt, it is requisite that the centre line of the belt be the centre line of the hide, thus having half the width each side of the back-bone; hence belting should be stretched in strips after cutting, as it has been proved that a whole hide will stretch only one inch in length, while the centre strip from the same hide when cut will stretch four or five inches more in a length of four feet.

The *grain* or *smooth side* of the belt is much weaker than the flesh side, and lighter in color, as will be seen on examining a freshly cut piece of leather. Its texture is more spongy, and it is full of minute holes or pores where the hairs have been. This gives rise to cracking and crumbling, and also excessive stretching. The *flesh side*, being more compact and therefore stronger, should be placed on the outside of the belt. Experiments have proved that belts give off 34 per cent. more power with the grain side towards the pulley. Very little of the strength of the belt is lost by wearing away the weaker side; in fact, with specially high quality double belts, makers shave away the grain side of each piece and put those two faces together in making up the belt.

The strain exerted upon a belt is the combination of two forces, namely, the pull of the belt in driving, on the one side of the pulley, and the effect of the weight of the slack side upon the other. The force tending to rupture the belt is the *sum* of these two opposing pulls, and the force available for purposes of driving is the *difference* between them. This in a measure complicates the problems concerned with a belt's strength, and other factors enter into the calculations, namely, the different degrees of friction between various belt materials and differing styles of pulleys, and the arc of contact between the belt and the pulley. Again, the strength of a belt is only equal to that of its weakest part.

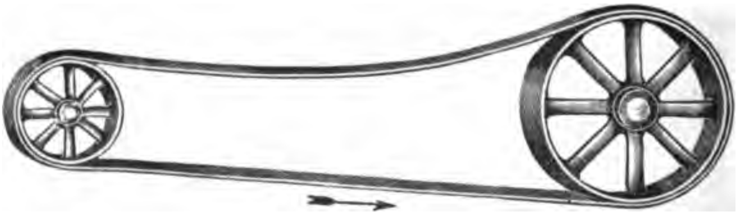

Fig. 314.—See page 287.

The place where the ends of a belt are joined is the part which possesses the least strength. The ends of belting are fastened together by various devices and laces of various descriptions. While the tenacity or tensile strength of good new belt leather varies from 3,000 to 5,000 lbs. per square inch, a mean of 4,000 may be taken. With this estimate then, with various joints, the following summary of the net strength may be safely followed :

TABLE.

Ordinary single leather	lacing=	950	lbs.	per	square	inch.
" " rawhide	"	1,000	"	"	"	"
Good double leather	"	1,200	"	"	"	"
" " rawhide	"	1,400	"	"	"	"
Ordinary rivetted joints	"	1,750	"	"	"	"

Leather belts can be made and repaired from readily obtainable material and without special machinery; can be easily cut and mended; are not affected by grease; run well crossed or twisted. They, however, change in length with atmospheric condition; cannot be used in damp places unless especially prepared for that purpose; and do not transmit power as well as rubber.

TABLE.

SIZES OF LACES AND PUNCHED HOLES.

WIDTH OF BELT.	WIDTH OF LACE.	SIZE OF HOLE.
2 inches or less.	$\frac{1}{4}$ in.	$\frac{1}{4}$ in.
2 to 4 inches.	$\frac{5}{16}$ in.	$\frac{5}{16}$ in.
4 to 8 inches.	$\frac{3}{8}$ in.	$\frac{3}{8}$ in.
8 to 15 inches.	$\frac{1}{2}$ in.	$\frac{1}{2}$ in.
15 inches and upwards.	$\frac{3}{4}$ in.	$\frac{11}{16}$ in.

The ends which butt together must be cut perfectly square; the belt will stretch more on one side than the other. Butt joints are not as strong as lapped joints, but are indispensable for belts working over tighteners, jockey-pulleys, etc.

HORSE-POWER OF BELTING.

A question often asked is :—How many horse-power can be transmitted by a certain size of belt?

To facilitate the solution of this problem, a brief tabular statement may save much calculation. Allowances have been made for the pull on the slack side of the belt, and ordinary differences between the diameters of the various pulleys :

TABLE

of strengths of belting materials.

Description of Belting.	Pull transmiss ble by each inch in width of belt.	Divisor by Rule for Horse-power.
Light single leather.	35 lbs.	3600
Good average single "	45 "	2800
Heavy single "	53 "	2380
Light double "	67 "	1880
Average double "	75 "	1680
Heavy double "	84 "	1500
Triple "	100 "	1250
Leather links, ⅜" deep.	42 lbs.	3000
" ½" "	48 "	2625
" ⅝" "	57 "	2141
" ¾" "	66 "	1910
" ⅞" "	78 "	1616
" 1" "	90 "	1400

RULE

for finding the strength of belts by use of the preceding table.

(1) Multiply *the diameter of the pulley in inches* by *the number of revolutions per minute ;* (2) Multiply *the product* by *the width of the belt in inches ;* (3) Divide *the result* by *the divisor found in the preceding table, corresponding to the style of the belt in question.* The answer will be the *total horse-power that may be supplied* by the belt.

EXAMPLE.

To find the horse-power which can be carried by a heavy double leather belt, suitable for a main drive, having a width of 15 inches: the engine fly-wheel, which also acts as a pulley, being 10 feet in diameter and running at 85 revolutions per minute.

```
                         120=diameter of wheel.
                          85=revolutions.
                        ----
                         600
                        960
                        ----
                      10,200
                          15=width of belt.
                      ------
                       51000
                      10200
Divisor from         -------
      table=1,500 )153,000(102=Horse-power transmissible.
                   150 0
                   -----
                     3 000
                     3 000
                   -------
```

It is better to make the lower side of a belt the driving one, as then the sag helps the belt to encircle a larger proportion of the circumference of the pulley, as in Fig. 314. The figure is self explanatory—the arrow showing the direction in which the belt travels; the larger pulley being the driver and the smaller, the driven. See page 284.

What is known as *quarter-turn driving* is used where two shafts run at right angles to each other, and not in the same *plane*. This is exemplified in Fig. 315.

QUARTER-TURN DRIVING.

When it is desired to effect the transmission of power in this case, experience has proved that certain conditions are necessary. 1, The distance between the faces of the pulleys must be not less than four times the width of the belt, or, if possible, twice this distance ; 2, the driving pulley should be wider than the other in the proportion of five to three, and should have a somewhat greater convexity than is commonly given to the face of a pulley; 3, both pulleys should be as small as possible, in view of the power to be transmitted, and ought to be nearly the same size; 4, the position in which they are placed relative to each other must be such that *the belt leads from the face of one to the centre of the face of the other.* This last condition is shown in Fig. 315, where a perpendicular line from the centre of the small pulley just touches the edge of the larger one.

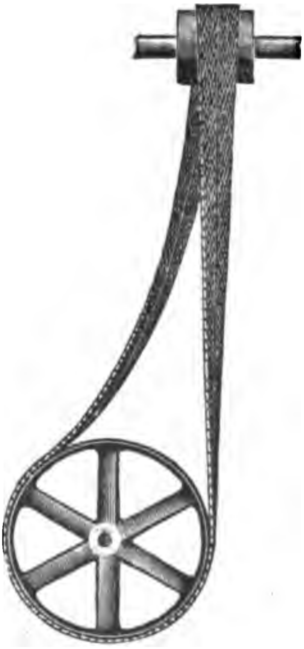
Fig. 315.

About twenty-five per cent. of the contact is lost with a quarter-turn, even when the pulleys are of the same size, owing to the imperfect elasticity of the ordinary belt, which is forced from the pulley by its own stiffness in making the twist. The use of the leather-link belt illustrated minimizes this loss, and as

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NOTE.—Some belts for quarter-turn drives are made double, the upper layer being much narrower than the other, and to one side, depending upon whether it is right or left-hand running. The inequality of thickness forces the thin side to the pulley and makes the contact good.

GUIDE PULLEYS.

the particular belt in question is hinged down the middle, it accommodates itself readily to the convexity of the pulley.

Wherever the faces of the two pulleys have to be very near each other, or the shafts are not exactly at right angles, *some form of guide pulley is necessary.*

A good arrangement is shown in Fig. 316, where the belt passes around a small guide pulley on *an idle shaft* before passing to the driven pulley, returning around another idler on the same shaft before returning to the driver pulley. With this arrangement, the same side of the belt is always in contact

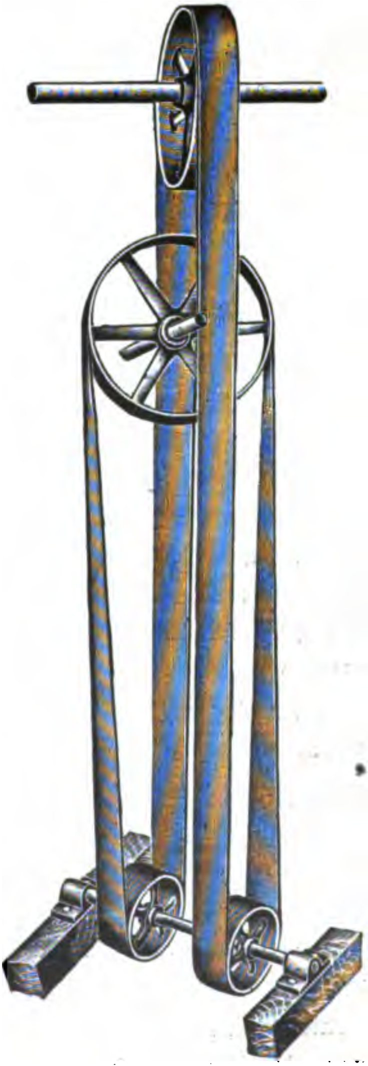


Fig. 316.

NOTE.—The difficult point is in laying out the position of the idler shaft. It must bisect the angle made by the two shafts, that is, it *should lie at an angle of forty-five degrees with each, when viewed from above.* Its plane should be parallel with the planes of the other shafts, and the position of the small pulleys should be determined by lines led from the face of one pulley to the centre of the face of the other as before.

with the various pulleys, and the area enveloping the pulley is much as it would be with a plain drive. Both recommendations are greatly in its favor.

It will be found beneficial to have one of the small pulleys loose upon its shaft, in view of possible inequality of rotation.

In the illustration it may be assumed that the two larger pulleys are one and three-quarter times the size of the smaller, the distance between the two forces is nine inches, and the distance between the upper shaft and the idler is equal to eighteen times the width of the belt.

Link belts, similar to that illustrated in Fig. 315 and on an enlarged scale in Fig. 317, are approved; the small pieces of leather are fitted together by steel pins or wires, and the result is a more flexible belt, accommodating itself with readiness to slight inequalities in the drive. The openings permit air to escape, and there is a firmer grip. Cases have occurred where the introduction of link belts has proved a remedy for many belting "troubles."

This type of belt runs almost perfectly true, and stretches but little, running well with the under side as a driver, and with a considerable amount of sag on the slack side.

The most reliable form of the connection for belting is the *lap and cement* joint. The overlap should be cut down to a plain bevel, the length of which depends upon the width of the belt; this varies from four inches with narrow single belts to seven or eight with wide ones; double belts should have a lap of six inches.

This bevel is best cut with a special plane or drawing-knife, upon a level surface, thus assuring a good and even performance.

CEMENT JOINTS.

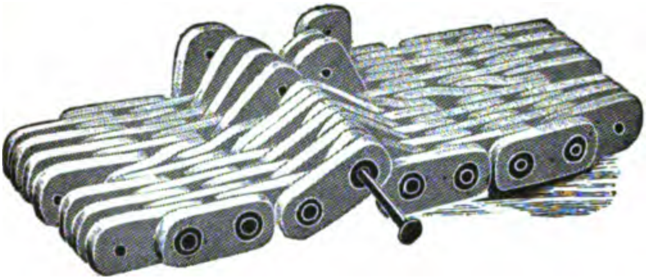


Fig. 317.

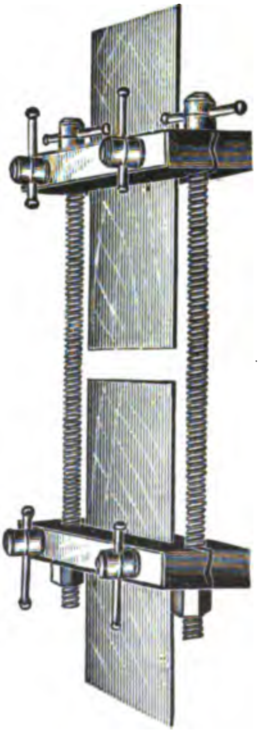


Fig. 318.

Leather should be cleaned from oil and grease by spreading a rag on the surface and placing a hot flat-iron upon it. After the two edges have been pared and thoroughly cleaned, the cement is spread over both pieces, and they are put together, ***being subjected to pressure until the cement has set.*** A pair of hot planed boards between which the belt is placed and weighted make an effective job; the heated boards can also be used to take the chill off the leather before jointing. Finally, *in the case of* leather belts, small wooden pegs such as are used by shoemakers should be driven through the belt and their ends trimmed flush.

NOTE.—Belt cement can always be purchased, but if it is desired to be made on the spot, a good recipe is as follows:—Mix ten parts of bisulphide of carbon and one of oil of turpentine, then dissolve in it a sufficient quantity of gutta-percha to form a paste. *Be careful in using as it is a violent poison, and very inflammable.*

LACED JOINTS.

In *handling* heavy belts, especially those of rubber which have to be cut very short to allow for stretching, some form of belt clamp is necessary to hold the ends for the purpose of joining the ends. Such an appliance is to be seen in Fig. 318, which shows *the clamp* or *stretcher* in use. Rotating the vise-handles attached to the stretching screws brings the ends of the belts together, and the operation of jointing is then completed.

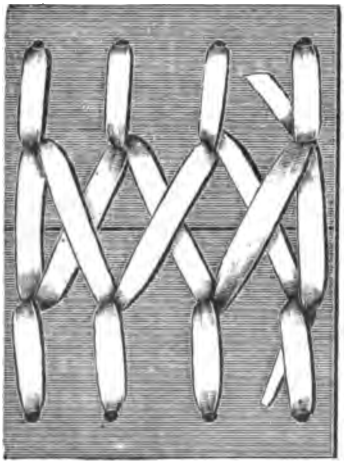


Fig. 319.

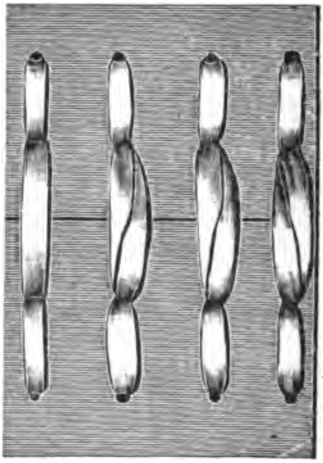


Fig. 320.

Laced joints are made more rapidly than cemented ones; they are divided into three classes, *lap*, *butt* and *apron* joints, each suitable for a separate purpose.

A good method of lacing a four-inch belt is shown in Fig. 319, which represents the outside appearance. The smooth finish given to the inside of the belt is shown in Fig. 320. The lacing used is $\frac{5}{16}$ inch oil tanned leather, and the first row of holes is punched 1" from the end of the belt, the second row $1\frac{1}{8}$" back

LACING.

of these, while the holes on the side are $\frac{3}{8}''$ from the edge. The number of holes across are equal to the number of inches in the width of belt.

Commencing to lace from the side of the belt, the ends being passed from the inside, each end is then passed through the hole in the opposite end of the belt, making two thicknesses of lacing on the inner side. Each lacing end is then passed through the hole in the back row and again through the same hole as before in the first row, thus filling the four holes at the side and leaving the lacing straight with the length of the belt. Both ends of the lacing now being on the inside of the belt, they must be put through the second hole in the first row on the opposite end, thus causing the lacing to cross on the back or inside of the belt. The ends are now put through these same holes again, opposite end through opposite hole, making two strands of lacing between this set of holes on the face side, the strands being straight with the length of the belt. The ends again being on the back of the belt are now to be put through the second row of holes and again through the corresponding holes in the first row, which brings the ends again to the back side of the belt ready to be crossed as they are put through the next set of holes, and so on until all the holes are filled.

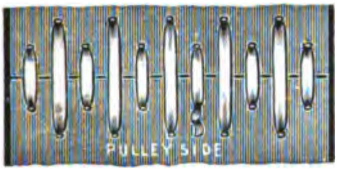


Fig. 821.

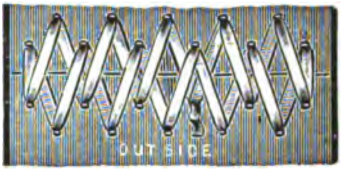


Fig. 822.

BELTING TOOLS.

This makes a lacing double on the outside ana smooth single strands crossing on the back and a straight pull on each strand on the face as it passes through each of the four holes in line. As the lacing is drawn through each of the four holes, the ends will be found securely fastened, and will bear a strand or two being cut. It is necessary to use pliers to draw the laces through the holes.

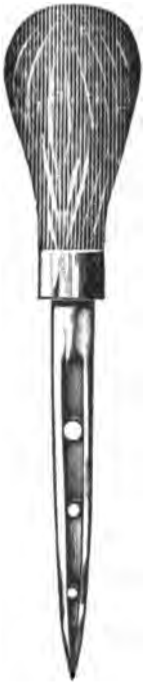


Fig. 323.

For laced belts, the *awl* shown in Fig. 323 is of service ; no punch is required with it for single belting. It is, however, advisable to use a small drive punch with double or rubber belts. The awl is thrust through from either side, until the first, second or third hole (according to the size of lace demanded) is visible on the opposite side of the belt. The end of the lace is inserted, *from the point of the awl*, through this hole ; in pulling the awl back, the lace is drawn through the belt.

In making *butt-joints*, the holes should be one inch apart, and about five-eighths of an inch from the edges of the belt. If placed zig-zag, each row of holes across the belt should be half an inch behind the next.

A simple and reliable method of lacing a belt joint for use with india-rubber belting is shown in Figs. 321-322, views of both front and back being given.

NOTE.—The groove in the awl is provided with one cutting edge, so that, twisting it to the right, it will cut the hole, but on turning it to the left, the hole in the belt is simply expanded without cutting.

RIVETED JOINTS.

Riveted joints, in which copper rivets and burs or washers as illustrated in Fig. 325 are used, have the merit of quick application. As the area covered by the washer and head is small, the strain at the joint is transmitted over only a portion of the leather; however, the use of rivets can be recommended only for joints that are not likely to be disturbed.

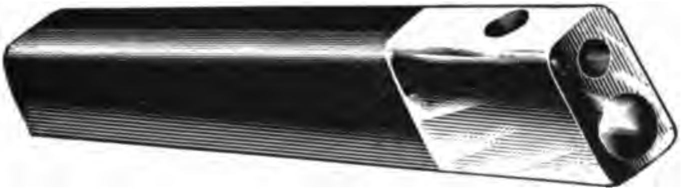


Fig. 324.

Fig. 325.

The tool illustrated in Fig. 324 serves as a *set* and *header* combined. One of the small holes is brought opposite the rivet-hole, on the other side of which the rivet has been entered, with its head resting upon something solid; a tap with the hammer upon the set forces the belt upon the rivet. The cup portion of the set is then used to complete the operation.

The *apron joint*, consists of a butt joint with a covering or apron of the same material. This apron is gradually chamfered towards each end, to enable it to bend easily around the pulleys.

Various forms of metallic belt fasteners are illustrated in Figs. 326–331. Their use needs little description.

BELT FASTENERS.

What is known as a *belt-stud* is seen in Fig. 326. This type is much used with rubber belts and possesses great resisting power. It is extensively used for light belting, as the ends of the belt are kept close together and the fastening does not come into contact with the pulley. The slits are cut in the material parallel with the length of the belt, and the fastening inserted as in Fig. 327, care being taken that the cut stops from one-quarter to three-eighth inch short of the end of the belt, the latter distance being recommended for use with rubber. Half an inch is advised as a good pitch for the studs. Fig. 329 represents the outside and Fig. 330 the pulley side of a belt joint made with these fasteners.

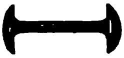


Fig. 326.

A fastening specially for rubber belts is illustrated in Fig. 331; this has a substantial double bearing in each piece of the belt and consequently there is less risk of tearing away the fabric at the corners of the holes.

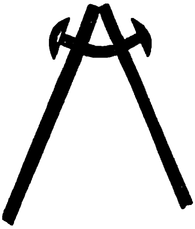


Fig. 327.

A common type of *belt-hook* is shown in Fig. 328, which is made in different sizes as illustrated. This is very easily applied, the ends being thrust through holes in each part of the belt from the back, and then clenched down to fasten.

These are but few of many ingenious and well tried belt fastenings.

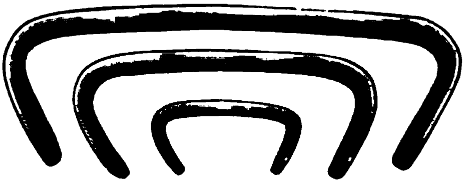


Fig. 328.

METALLIC FASTENERS.

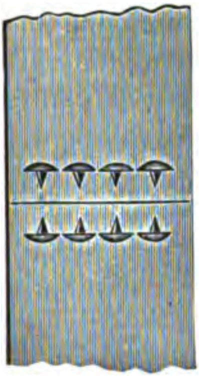


Fig. 329.

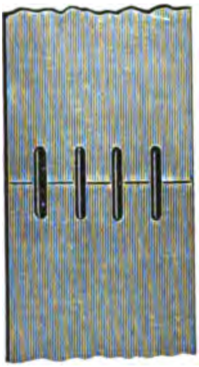


Fig. 330.

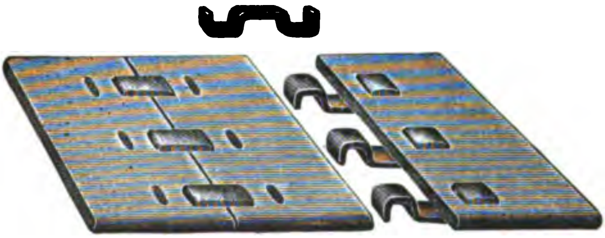
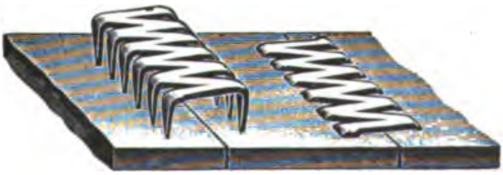


Fig. 331.



BELT TIGHTENERS.

When a heavy belt has only a short "drift," as it is termed, the centres of the driving and driven pulleys being close together—more especially when the difference between their diameters is large—the arc of contact on the driven pulley is likely to be small, and slipping will result. In such a case, recourse is had to a *tightener*, such as is seen in Fig. 332. The pulley rides *upon* the belt, hence it is frequently termed a "jockey pulley," and presses the *slack side in toward the centre line of the two pulleys*, thus causing the belt to envelop a larger portion of the circumference and giving a better drive. The tension of the belt is regulated by the rack-and-pinion gear, manipulated by the hand wheel seen on the right of the illustration, and the pinion shaft is locked by a pawl engaging in the ratchet wheel shown near the hand wheel.

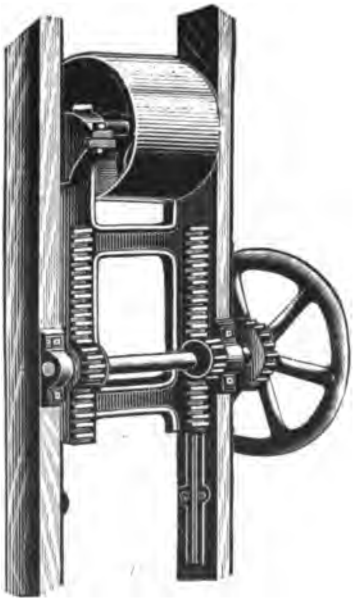


Fig. 332.

RUBBER BELTING.

Rubber belting is made of stout cotton duck alternating in layers with india rubber, the whole being subsequently vulcanized; this process consists of treating crude, or native, india rubber with sulphur at a high temperature, thereby increasing both its strength and its elasticity. It is denominated according to the number of layers or "plies" of duck, each ply averaging $\frac{1}{16}$ of an inch in thickness. The better qualities are made from fresh rubber; the cheaper grades contain what is known as "reworked rubber."

Owing to its greater flexibility in accommodating itself to the nature of the drive a rubber belt will transmit from one-eighth to one-fourth more power than leather with the same arc of contact; it is claimed that six-ply rubber belting gives results equal to double leather.

There are some serious drawbacks to the use of rubber belting; (1), they are not suitable for work in situations where the temperature is over 90° Fahr.; (2), if used on shifting drives, the edges become frayed and worn; (3), they cannot be used in connection with jockey-pulleys, tighteners and the like; (4), some particular fastener has to be substituted for *lacing*, such as that illustrated in lower figure, page 297.

Large rubber belts stretch considerably, and an allowance of three-sixteenths of an inch per foot must be made in cutting the length required.

Cotton belting is a woven cotton fabric. Several folds or plies of duck or canvas are stitched together in the direction of the length of the belts, and subsequently treated with a compound consisting chiefly of linseed oil.

TEXTILE BELTING.

This mixture contains various preservative agents and also a *red pigment* which gives the belting its characteristic appearance. The oily compound saturates the belt and protects it from wet and dampness, while it is not easily injured by heat or cold, steam or gas and acid fumes. In many cases cotton belts will work admirably where the surroundings and atmosphere would ruin leather or rubber belts. Cotton belts must be united by some form of metallic fasteners as a general rule, the stiffness of the fabric militating against the use of laced joints. An efficient type of fastening, which is specially suited for cotton and other textile belting, is seen in the lower figure on page 297. It is quickly applied and grips tenaciously. The illustration shows its method of application, and its appearance when finished.

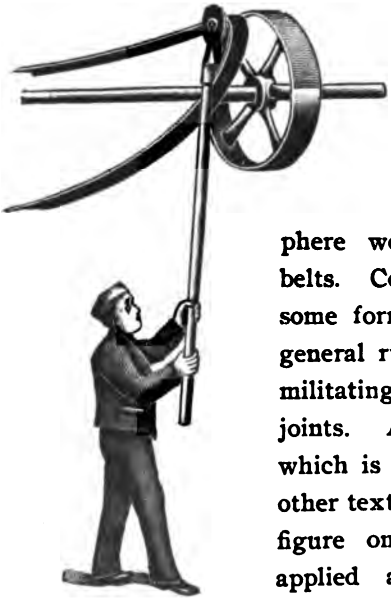


Fig. 333.

To prevent accident when putting on belts, the *belt slipper*, Fig. 334, has been devised. The cone and shield, marked A in the engraving, revolve upon the stem, B, thus yielding easily to the pull of the belt. A staff or handle C of any convenient length can be fastened to the socket. The mode of operation is illustrated in Fig. 333, which is self explanatory.

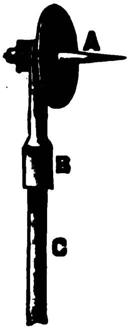


Fig. 334.

SAFETY APPLIANCES.

A light *safety ladder* for use with shafting is illustrated in Fig. 337. Its method of use is better seen from the side view shown in Fig. 335. In view of the numerous accidents occurring through the slipping of a shop ladder, such provision seems eminently desirable. The shape of the hooks which encircle the shaft, the method of fastening, and the rounded ends are well shown in detail in Fig. 336.

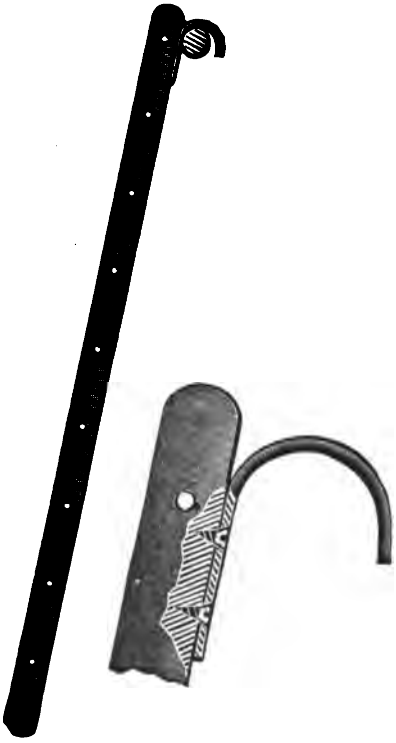


Fig. 335. Fig. 336.

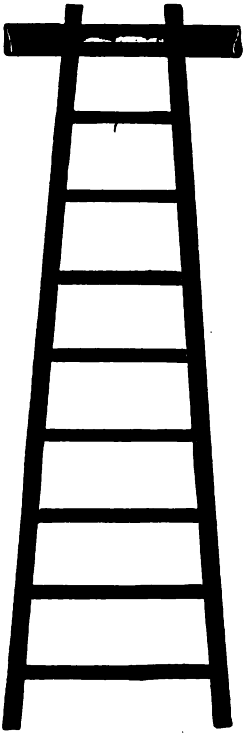


Fig. 337.

TABLE

showing the speed necessary for a leather belt to transmit one horse-power for each inch of width.

Diameter of Pulley.		Single Belting.	Double Belting.
Ft.	Ins.	Feet per Minute.	Feet per Minute.
	6	6,400	....
1	0	3,200	....
1	6	2,400	1,333
2	0	1,600	1,000
2	6	1,240	875
3	0	1,066	730
3	6	950	625
4	0	800	500
5	0	680	400
6	0	533	335
7	0	457	286
8	0	400	250
9	0	355	225
10	0	250	160

This table is based upon the fact that a belt moving at a moderate speed on a large pulley is more effective than one of equal dimensions running quickly over pulleys of small diameter.

TABLE OF EQUIVALENT BELTING.

Leather.	Cotton.	India Rubber.
Light single.	....	2 ply.
Medium "	4 ply.	3 "
Heavy "	5 "	4 "
Light double.	6 "	5 "
Medium "	....	6 "
Heavy "	8 "	7 "

TO MEASURE LENGTHS OF BELTS.

The diameter of the pulleys and the distance between their centres being known.

Rule. Where the belt is what is known as an *open* one:—(1,) Add together in inches the diameter of the two pulleys, (2,) halve the result, (3,) multiply the quotient by $\frac{22}{7}$ or 3.1416, (4,) add in inches twice the distance between centres. The result is the *length of the belt in inches.*

Example:—The pulleys being 28 in. and 21 in. respectively, and the countershaft 18′6″ from the driving or main shaft, now,

By the rule 28 } two pulleys
21

2)49

24.5
22

490
490

7)539.0

12)77 inches

6′ 5″

18 ft. 6 in.
2

37 " 0 "
add 6 " 5 "

43 ft. 5 in.

The 43′ 5″ above is the length of belt without the lap for which allowance must be made.

When the length of a *crossed* belt is required, and the pulleys are not erected on the shafts, it is, on account of the abstruseness of a calculation for the purpose, preferred in practice to mark off by lines the pulleys set at their proper distance apart (either full size or to scale), and measure the length of the side of the belt, supposing the belt to envelop one-half the circumference only of each pulley, and to add to this one-half the circumference of each pulley; or if there is a great difference between the relative diameters of the pulleys and the distance apart of the shafts is unusually small, the lengths of the straight sides of the belt are measured and the arcs of contact around the pulleys are stepped around by compasses, the set of the compasses being not more than about one-tenth the circumference of the pulleys.

This gives a closer result than that obtained by calculation, because, although it will give a belt shorter than by calculation, the belt will be too long on account of the stretch necessary to the tension required for ordinary conditions.

In narrow belts, as, say, three inches and less in width, the belt may be cut to the length of *a tape line passed over the pulleys*, and when placed over the pulleys it may be strained under a hand pull and cut as much shorter as the tension under hand pressure indicates as being necessary. But if the belt is a wide one a stretching clamp, such as shown in Fig. 318, is employed, the screws being right hand at one end and left hand at the other, so that operating them draws the clamps, and therefore the ends of the belt, together.

NOTE.—The following simple and sufficiently accurate rule is given for the benefit of those who do not wish to make a careful scale drawing, to calculate the length of the straight sides of a crossed belt.

RULE. *Square the mean diameter of the two pulleys; square the distance between the shaft centres; add these two squares together and extract the square root of their sum.*

Assuming the dimensions of the previous example: the mean of 28 and 21 is 24.5, and 24.5 x 24.5=600.25; 18′ 6″=222,″ and this squared is 49284; the the sum of the two squares is 49884.25, and the square root of this is 223.35 or 18′ 7⅜.″ Substituting this for 18′ 6,″ the length of the same belt, if crossed, is found to be 48′ 7⅜.″

BELT DRESSINGS.

Attention should be paid to the condition of belts so that their driving faces may be kept pliable; this may be effected by the use of a good belt dressing. Perhaps the best dressings approximate to the *dubbing* used by firemen to preserve leather hose, or by sportsmen to keep their heavy shooting boots pliable. This consists of a mixture of fish oils and animal fat applied in the form of a soft ointment, and worked in with a medium brush.

An approved *recipe for dressing* is as follows:—Prepare tallow by boiling it in water, so that the latter may take up the salt and dirt, which may be poured away when cold. Re-melt the *perfectly clean tallow*, and, when it is warm pour in *cod oil*, in the proportion of 1 gallon to each 2 lbs. of tallow, stirring until the mixture is cold. The oil *must not be boiled*, as that destroys its valuable qualities.

Apply this dressing with a square brush, such as is used for cleaning shoes, and rub it on *both sides* of the belt. A belt so treated will run slacker, and "suck" the pulley better than a dry one.

If a belt is pliable and only dry and husky, apply blood warm tallow, drying in by heat of the fire or the sunlight.

A hard and dry belt may be restored to suppleness by the application of neat's foot or cod liver oil mixed with a *small* quantity of resin.

A little resin may be used with advantage in the tallow applied to " supple "such belts as have to work in wet places.

Boiled linseed oil makes an efficient dressing for cotton belting; it soon oxidizes, and gives the belt an elastic gummy face.

NOTES RELATING TO BELTS.

After the elastic limit of a leather belt is reached it may be stretched to the breaking point without getting it any tighter.

The friction increases regularly with the pressure; the more elastic the surface the greater the friction.

To obtain the greatest amount of power from belts, the pulleys should be covered with leather; this will allow the belts to run very slack and give more wear.

The leather in a belt should be pliable, of fine close fibre, solid in its appearance, and of smooth polished surface.

Belts derive their power to transmit motion from the friction between the surface of the belt and the pulley, and from nothing else.

The thickness, as well as the width of belts, must be considered; consequently, a double belt must be used where it is necessary to transmit a greater power than possible with a single belt.

To increase the driving power of a belt, the pulleys may be enlarged in circumference, thus increasing the speed of the belt. This can often be done to advantage, provided that the speed be not carried above the safe limit.

The width of a belt needed depends on three conditions: 1st, the tension of the belt; 2d, the size of the smaller pulley and the proportion of the surface touched by the belt; 3d, the speed of the belt.

The adhesion, one inch in width of the belt has on the pulley is the number of pounds which each inch in width of belt is capable of raising or transmitting. Multiplying this by the velocity of the belt in feet per minute will give the total number of pounds each inch in width will raise or transmit one foot per minute. The answer is in foot pounds of which 33,000 equal 1 horse power.

LINE SHAFTING.

The word shafting is purely mechanical and is in a majority of cases used with the word belting : i. e. "*shafting and belting*:" otherwise it becomes shaft; which term is applied to many things. Shafting is used to convey the force which is generated in an engine or other prime mover to the different working machines, for which purpose it is provided with pulleys and belts or with cog-wheels.

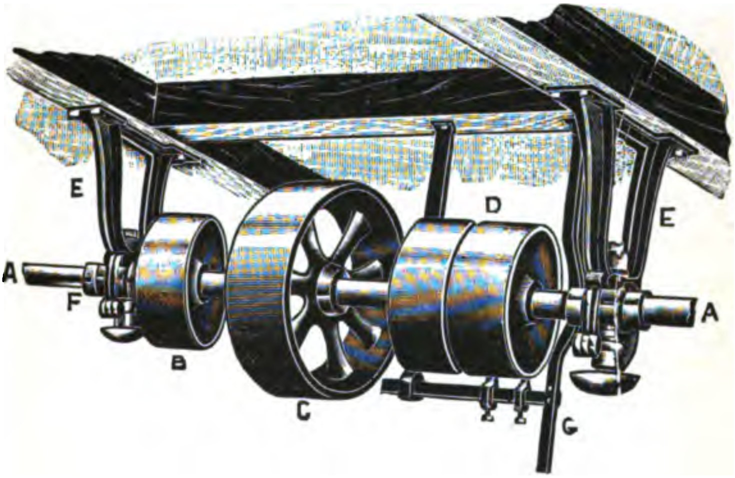


Fig. 338.

Fig. 338 shows an arrangement of a portion of line shafting, with pulleys, hangers, etc. The references are AA, shaft; B, plain pulley ; C, spoke pulley ; D, fast and loose driven pulleys; EE, hangers to support shafting ; F, stop collar to prevent end play ; G, belt shifting gear.

Flexible shafting is composed of a number of wires wound spirally, one over another, used to convey power for short distances to tools that require to be moved about or changed in position or direction.

LINE SHAFTING.

The determination of the proper size of shaft to transmit any required power at any given speed is a simple matter if it is to be subjected to torsion or twisting only. Generally shafts are also subjected to transverse or bending strains, due to the weight of pulleys and gears and the pull of belts, which somewhat complicates the problem. Therefore in fixing the size of shaft these conditions should be considered and the shaft made of large enough diameter to resist twisting and undue deflection. It should not, however, be made larger than necessary, as greater size means increased first cost and added operating expense.

It is usual in settling the dimensions of a line of shafting, to consider each individual length separately, according to the power transmitted by it. Accordingly the diameters gradually lessen as they recede from the point where power is applied, thus lessening weight and cost, although it necessitates bushings for pulleys, etc.

The class or character of loads to be driven should always be taken into consideration, whether steady or variable; and if variable, whether variations are great or sudden, etc. Where rigidity between bearings is desirable, it is sometimes obtained without materially increasing the journal friction by using large shafts, and reducing them at the bearings to a smaller diameter, the shoulders thus formed acting as collars to prevent end motion of the shaft.

Two chief forces act upon shafting, the *torsional or twisting strain* by which the power is imparted, and *a bending or transverse strain* set up by the pull of the various belts and by the weight of the pulleys and shaft itself. Shafts must be of sufficient size to prevent bending or else must have the hangers so near to each other that they will bend very little.

LINE SHAFTING.

The weight of the pulleys and shaft is downward, and the pull of the belts may be up or down or at any angle. It follows, then, that a shaft loaded with pulleys must have a larger number of hangers than would be required for an unloaded shaft, and that the pulleys must always be placed as near to the hangers as possible.

Shafting increases more rapidly in stiffness than its diameter, its strength being in proportion to the cube of the latter. Thus a 4" shaft instead of being only twice as strong as one of 2" diameter, can transmit eight times the power. Cubing each number, that is, multiplying it by itself twice, the results are 4 x 4 x 4=64, and 2 x 2 x 2=8, and the former result is eight times as large as the latter. Similarly if a 1-inch shaft will drive 3-horse power, a 2-inch shaft will drive as much more as the cube of its diameter is in excess of the cube of 1. The cube of 2 is 8, and therefore its comparative power is 8 x 3=24-horse power, and the cube of 3 being 27, its power in this case is 3 x 27=81-horse power. To use a shaft of 3 inches diameter, instead of 2 inches, would have given in this case a shaft capable of driving 81-horse power, instead of 24.

On this basis, a 1-inch shaft having a strength of 1, a 2-inch shaft would have a strength of 8, a 3-inch shaft a strength of 27, a 4-inch shaft a strength of 64, a 5-inch shaft a strength of

---

The bending of a shaft causes a considerable loss in power from the friction of the shaft in its bearings beside the tendency of the shaft to break. The bending and twisting of the shaft both contribute to break it, but the bending has most to do with it. Shafts, therefore, should be of such size that they will not bend more than $\frac{1}{100}$ of an inch per foot in length.

125, and so on, as the cube of the diameter. This fact of the rapid increase in the strength of shafting with a small increase in diameter should be borne in mind; and likewise that this strength varies as the cube of the diameter.

Another point is, *the power that a shaft will drive is in direct proportion to its speed.* If a shaft drives 3-horse power at 100 revolutions per minute, at 200 revolutions it will drive 6-horse power, and at 300 revolutions 9-horse power, and so on. Therefore, the faster a shaft runs the smaller may be the diameter in proportion for driving a given horse power. Shafts are subject to a torsional strain to twist them, and in long shafts or lines of shafting this becomes an important factor.

The friction of the belts and journals causes the far end of a shaft to lag behind the end at which the power is applied, and in a very long shaft, this difference of relative motion is great. A shaft should be strong enough to limit the twist to 1° in 20 diameters. For instance, a 2-inch shaft should not twist more than 1° in every 40 inches. This shaft would have to be 600 feet long to twist half a circle, or 180,° that is, for one end of the shaft to be one-half a turn behind the driving end. Where the power is taken off the end of a long line of shafting the twisting of the shaft will be more noticeable, and give so much trouble by oscillating that a balance wheel may be necessary.

On the other hand, heavy lines of shafting cost more money to put up and run them than in the case of light ones. *The larger shaft will take more power to turn it*, because it is heavier and its surface moves through a greater distance.

Taking the case of a 2-inch and 4-inch shaft, the 4-inch shaft weighs four times as much as the 2-inch shaft and this weight is moved through twice the distance because its circumference is twice as great. It is a costly proceeding from the standpoint of fuel-economy to put in heavier shafting than is necessary to do the work with the least amount of bending and twisting.

In very long lines of shafting the bearings should be nearer together toward the end of the line, and shafts running at a high speed should have the hangers nearer together to give a greater bearing surface to prevent heating. In cases where these rules are used the pulleys should be placed near the hangers or else the distance between hangers reduced. The rules give the maximum in either direction.

When locating shafts that are to be connected with each other by belts, care should be taken to secure *a proper distance one from the other.* No definite rule can be given as to what this distance should be. A general rule may be stated thus: where narrow belts are run over small pulleys, fifteen feet is a good average. For larger belts working on large pulleys, a distance of twenty to twenty-five feet does well. Shafts on which very large pulleys are to be placed for main driving belts should be twenty-five to thirty feet apart. It has been practically demonstrated where shafting has been located as above, that the belts work in a satisfactory manner. If too great distances are attempted, the weight of the belt will produce a heavy sag, drawing heavily on the shafts and causing extra friction on the journal bearings. Shafts connected by belt should never be placed one directly over the other, as in such case the belt must be kept very tight to do the work.

COLLARS.

It is desirable that the angle of the belt with the floor should not exceed 45°. *It is also desirable to locate the shafting and machinery so that belts shall run off from each shaft in opposite directions*, as this arrangement will relieve the bearings from the friction that results when the belts all pull one way on the shaft. If possible, machinery should be so placed that the direction of the belt motion shall be from the top of the driving to the top of the driven pulley, when the *sag will increase the arc of contact.*

To prevent end motion to a line of shafting it is necessary that there be fixed at some part of the line two shoulders or collars on different sides of the bearing, these collars meeting the side facings of the bearing.

It is preferable to place such collars one on each side of one bearing, so that the difference in contraction and expansion from varying temperatures shall be confined to the difference in expansion between the metal of which the bearing and shaft respectively are composed in the length of the bearing only, instead of being extended to the difference in expansion between the shaft throughout its whole length and that of the framework to which the hangers, or bearings, are bolted.

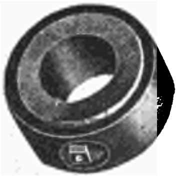


Fig. 889

As a rule it is preferable that the collars to prevent end motion to the shaft be placed at the bearing nearest the engine or motor; and this is especially desirable where bevel-wheels are employed to drive the shaft, because in that case the pitch lines of the wheels are kept to coincide as nearly as practicable, and the teeth are prevented from getting too far into or out of gear.

When shoulders are not formed, collars must be put on the shafts to prevent them from shifting. Great care should be given to the placing of the collars as the shafts vary in length for each change of temperature.

CONE FRICTION SHAFT CLUTCH.

Stop collars on shafting have been the subjects of a great deal of invention on account of the numerous accidents caused by the use of set screws to fasten collars on shafting. Fig. 339 represents one of these safety stop-collars, *fitted with a recess* or countersink for the head of the set-screw. This is a necessary provision as many serious accidents have resulted from workmen having their clothing caught in the projecting set-screws of the ordinary type of collar. For special purposes, these collars may be obtained split in two halves, united by bolts similarly sunk within the body.

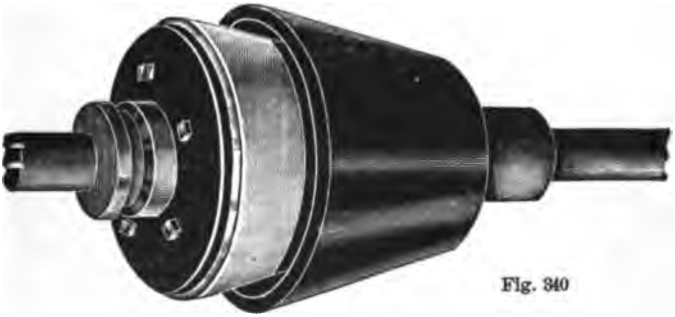


Fig. 340

Fig. 340 represents a cone friction shaft clutch. The outer half is a working fit upon the shaft, but is secured against end motion by the collar. The sliding half is coned and covered with leather as shown, the outer half being coned to correspond. The sliding half is driven by a feather fast in its bore, and sliding in a feather-way or spline in the shaft.

The driving power of the device is obtained by means of the friction of the coned surfaces. The transmitting capacity of the clutch depends upon the pressure applied to maintain the cones in contact. It is desirable that the end pressure be as small as possible.

NOTE.—The *hook-head key* used to fasten pulleys on shaft and the *set-screw* with projecting head have been the occasion of innumerable and cruel accidents, and their use is to be deprecated.

LINING-UP SHAFTING.

To arrange shafting in line is a task requiring the utmost skill, nicety of arrangement, and good judgment of the millwright, machinist, or engineer. To ***align*** shafting is to bring it in line. The definition applies to the mighty shaft of a steamship or the spindle of a sewing machine. The effective working of all kinds of machinery depends upon the proper placing of the shafting.

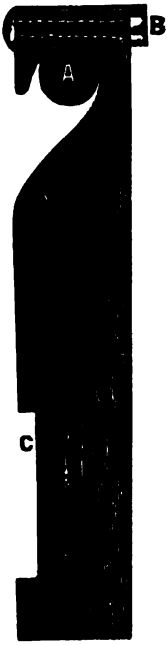


Fig. 341

Various methods of accomplishing the result are well known among craftsmen and are largely communicated from one artisan to another by verbal instruction.

A simple way of aligning shafting, when its diameter is the same throughout, is to provide two pieces of good, straight pine, four inches by one inch and seven-eighths, about twelve inches longer than the radius of the largest pulley, and cut out a circle in one end of each board a little larger than the diameter of the shaft. On the bottom end cut an offset about one and a quarter inches by eight inches as shown at C in Fig. 341. Before cutting the circle as at A, it is advisable to put a light carriage bolt through the end of the pine stick to prevent splitting. The bottoms of the offset, C, in each case must be exactly the same distance from the top of the circle, A.

LEVELING SHAFTING.

The manner of employment is to hang the two pieces on the shaft with a straight-edge resting in the slot or offset, C, and, by applying a level upon the top of the straight-edge, ascertain the truth or otherwise of the shafting.

If it is not possible to obtain a level, another method may be used which is illustrated in Fig. 342. The two pieces are fastened together as shown in the figure, care being taken to get the hangers square with the cross pieces. These hangers should be, perhaps, longer than with the previous method, as the braces must clear all pulleys. Taking a plumb-line board about six inches wide by three to four feet long, and fastening it to the top and bottom cross piece at or about the centre, perpendicular to the cross pieces, the plumb-line will hang in its proper vertical position, when the shaft is quite horizontal.

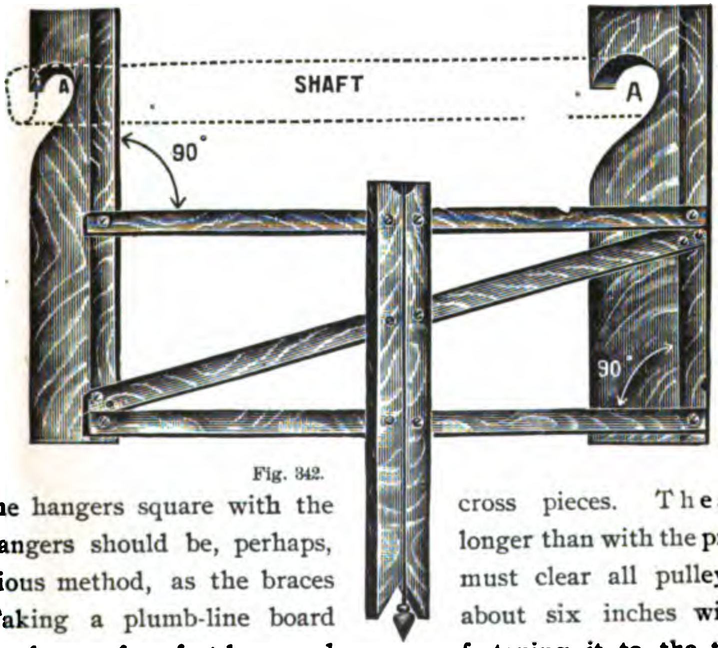


Fig. 342.

LEVELING SHAFTING.

Another useful leveling tool may be seen by referring to Fig. 343, which consists of two hooks, one of which is shown, of three-eighths-inch round iron. Both hooks must be made exactly the same, and the angle support at the other end wide enough to receive a leveling board with parallel edges.

After adjusting the angle supports to the same height when hanging side by side, perfect alignment of the shaft may be obtained by hanging the hooks from adjacent bearings and altering the screws of the latter until the level shows both points of support exactly the same height. The check nuts should then be tightened and the hangers are ready for use.

As with the device illustrated in Fig. 342, a spirit-level may be dispensed with by using a convenient plumb-line board attached accurately at right angles to the planed leveling board which rests within the brackets.

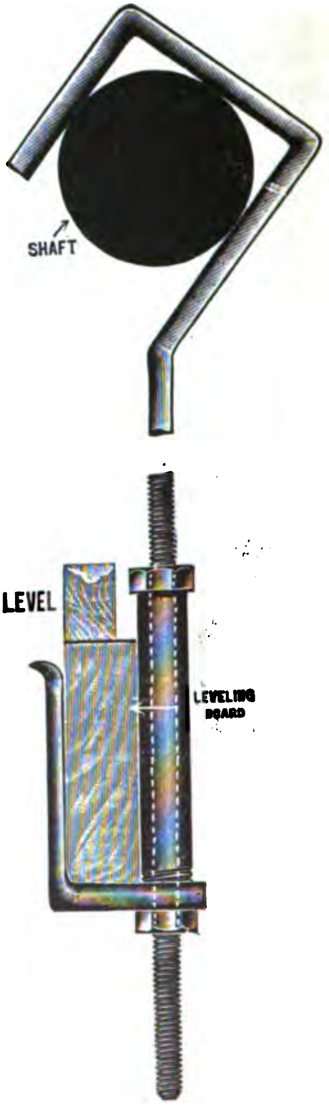


Fig. 343.

LEVELING SHAFTING.

A convenient form of shafting-level is shown in Fig. 344. It may be made of either brass or wood, and its superiority lies in the fact that the diameter of the shaft is immaterial to its action.

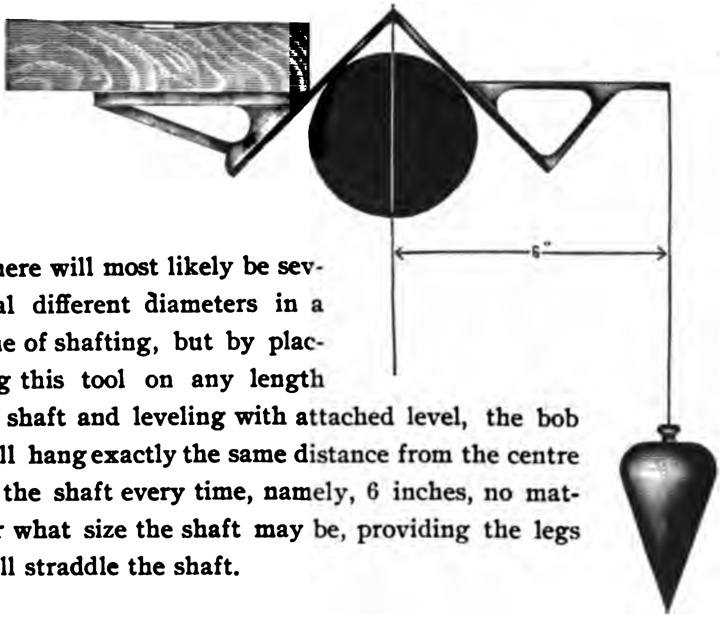


Fig. 344.

There will most likely be several different diameters in a line of shafting, but by placing this tool on any length of shaft and leveling with attached level, the bob will hang exactly the same distance from the centre of the shaft every time, namely, 6 inches, no matter what size the shaft may be, providing the legs will straddle the shaft.

In aligning the shaft horizontally, a fine wire, which will strain taut without much sag, should be stretched the length of the shaft, parallel to its proposed centre-line. The leveling device illustrated in Fig. 343 being employed, it is easy to measure from the plummet-line to the wire, and thus check the alignment of the shafting at any point in its length, notwithstanding variations of diameter.

NOTE—On account of its usefulness in laying out centre lines, the erector should always possess a coil of fine steel *piano wire.*

LEVELING SHAFTING.

In cases where head room is limited, or there is a deficiency of lifting tackle, a hoist may be improvised from ropes for dealing with lengths of shafting. Fig. 345 shows the general idea.

The centre rope is the hoisting one, those to the right and left are provided for purposes of safety, and to follow up the shafting as it is hoisted, to avoid accidents.

The bight of the rope is brought down and passed under the shafting, a pinch-bar is inserted, as shown in the engraving, and the shaft rotated by its means in the direction of the arrow. Each revolution of the shaft lifts it by an amount equal to its circumference, or more, according to the thickness of the rope. The two outside ropes, passing through the eye bolts, are kept under strain all the time the shaft is maintained in a horizontal position, and keep it from tipping.

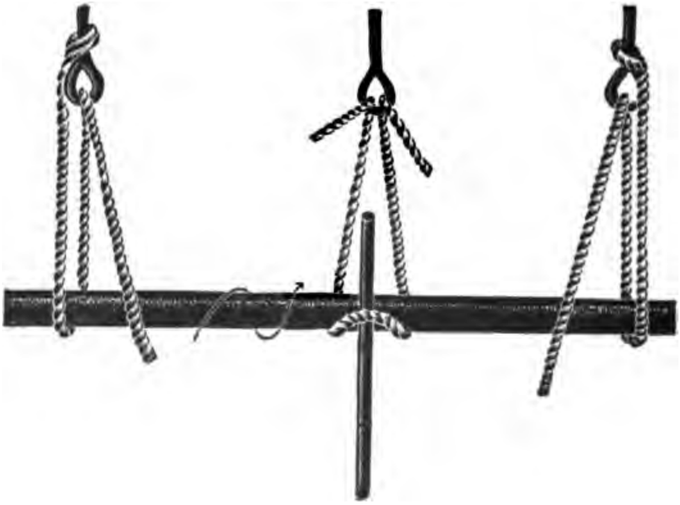


Fig 345.

LEVELING SHAFTING.

It will be evident that the pinch-bar illustrated in Fig. 345 may be replaced by the spoke of a pulley, and the application of the principle becomes apparent. Owing to practical difficulties concerned with jamming of the ropes, etc., it is inadvisable to pass the rope through the pulley, so that the arm is exactly similar to the bar in Fig. 345. Rather, it should be kept on one side of the pulley to avoid entanglements. Two men mounted upon ladders can effect the necessary rolling, while two others upon the floor manipulate the safety ropes.

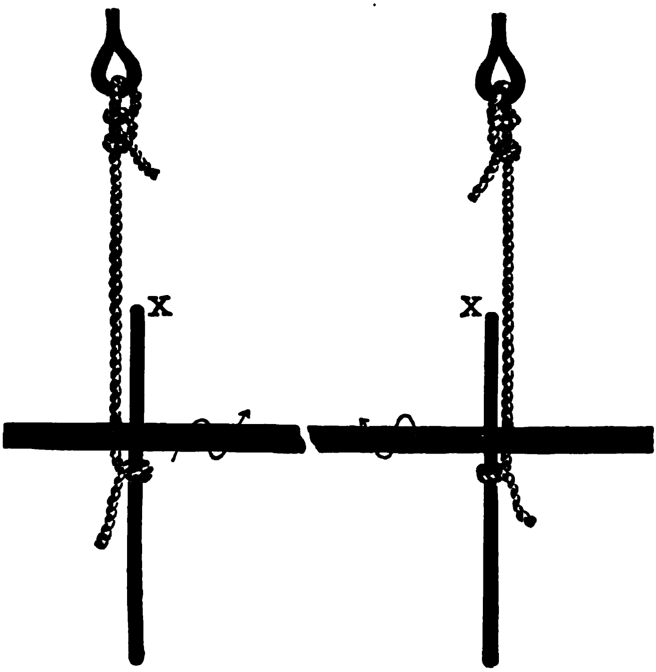


Fig. 346.

In cases where the pulleys are too small to serve as levers, and where the shafting is heavy, it is advisable to use two strong

RAISING AND LOWERING SHAFTING.

wooden or steel bars, as in Fig. 346, with safety ropes at each end. The two bars marked XX must be on the same side of the shaft, with the rope similarly bent, or else the shaft will not go up plumb. Fig. 346 also serves to furnish another plan of making fast the rope.

A further modification of the same rolling principle is given in Fig. 347, showing the end view of a shaft in lowering. The lowering rope is passed around the shaft a few times and its friction serves as a brake.

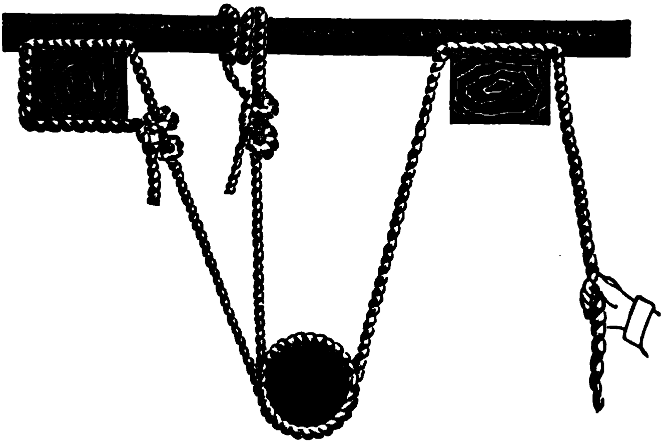


Fig. 347.

The *Spanish windlass* may be employed in many cases in connection with shafting, etc. A small line is passed several times under the shaft and over a beam, through an eyebolt or other convenient support, and the end made fast so as to form a loose lashing. Inserting a crowbar between the parts, the whole is twisted up together, the shortening of the sling due to the turning of the bar forming a powerful purchase.

SHAFT BEARINGS.

Supports for shafting vary in description accordingly as they are attached to a floor, a wall or a ceiling, and are diversified in form to suit the circumstances. Each of these varieties can also belong to one of the following classes:—

1. Those supports in which the bearing boxes are permitted to swivel, vertically and horizontally, and thus to adjust themselves in a measure to the axial line of the shafting; these swiveling supports have also means to provide a certain vertical adjustment for the height of the bearing.

2. Those bearing boxes which are incapable of these automatic adjustments, requiring accurate alignment and fitting in place, and needing careful work in taking up wear.

3. Bearings incapable of self-adjustment for position, and unprovided with means for taking up the slack due to wear.

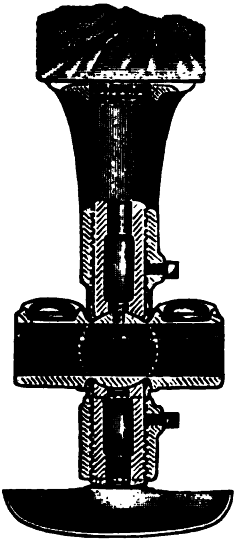


Fig. 848.

The bearings themselves vary widely in material. Sometimes plain cast iron is used for the friction surface, sometimes brass or gun metal, or some anti-friction metal (generally a tin-lead compound) is used in cast-iron or steel shells. American practice tends to the exclusive use of babbitt over other alloys, and the "brass" so general elsewhere is rarely employed.

SHAFT BEARINGS.

In dealing with the supports for line-shafting, the *hanger* is necessarily the most prominent, as the shafting is generally suspended either from the ceiling, or from pillars, posts, or the wall itself.

The method in which self-adjustment is obtained with a hanger-bearing may be gathered from Fig. 348, which illustrates a section of one of Sellers' ball-and-socket hangers, which have become standard in the United States.

The frame of the hanger is threaded to receive the cylindrical "plungers," which are screwed with a square thread outside, and therefore advance or retreat from the centre line of the bearing as they are turned one way or another. The inner ends of these plungers are cupped or concave where they abut against the halves of the bearing-box, and these latter being turned to a spherical form at their central portion, a ball-and-socket or universal joint is made. This permits of motion in any direction centrally to the ball formed on the bearing. Vertical adjustment is effected by rotating the screwed plungers, thus raising or lowering the bearing relatively to the frame.

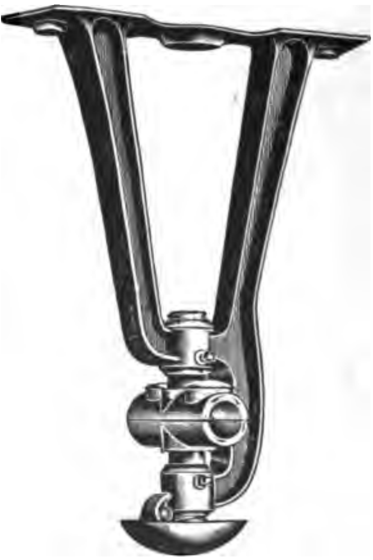


Fig. 349.

Often the central portion of the bearing-box of a pillow-block is also turned spherically, and works within a recess, frequently babbitted, formed in the yoke or main casting.

SELF-OILING BEARINGS.

In hangers of the second class, in which the self-adjusting features are omitted, it is necessary not only to accurately align the hangers, but also to fit all boxes to the shaft, which must be tried in place during the operation. The cost of performing this work, if properly carried out, more than counterbalances the difference in price between the simple hanger, and the more elaborate adjustable form.

The *open-side drop-hanger* shown in Fig. 349, presents many good qualities. It possesses the ball-and-socket joint already described, and is so arranged that the plungers may be retired, the bearings removed, and the hanger fitted to an existing line of shafting without removing either pulleys or couplings, or disturbing the shaft. Similarly, if the hangers are in place, it is a simple matter to remove the shaft if it should become necessary to do so.

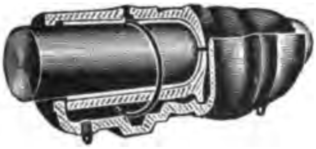


FIG. 350

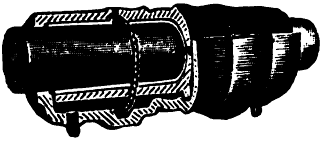


FIG. 351

For the sake of stiffness, the frame is frequently made double, as power generally has to be taken in each direction from a shaft. To provide for easy removal of the shaft, with this class of hanger, part of the frame, either at the side or bottom, is made removable, being joggled into place like a bearing-keep, and fitted with bolts.

NOTE—Many lines of shafting require much more power to run them than is actually necessary, because heavy machinery has been located on the floor above, thus causing it to settle and throw the shafting out of line. For this reason adjustable hangers are much preferable to the non-adjustable kind.

PILLOW BLOCKS.

A *post-hanger* is constructed similarly to a drop-hanger, save that it is attached as a bracket to a wall or pillar, and the centre line of the adjustable parts is therefore at right angles to the centre line of the frame. These hangers are all provided with a drip-cup of cast iron, to act as save-all for the oil used in lubrication.

Bearings may be divided into two types, *plain* and *self-oiling;* the former of which have no special device for lubrication beyond holes through which the attendant supplies oil, or through which grease may be fed by one of the many varieties of grease cups.

Self-oiling bearings are of the following types:—1. *Capillary lubricators,* in which oil is fed to the bearing through *worsted syphons, wicks, felt,* etc., from a reservoir; 2. *Ring* and *chain* oilers, illustrated respectively in Figs. 350-351, in which a solid ring or flexible chain of metal runs around on the shaft, dipping into a reservoir of oil below the journal, so lifting oil and carrying it to the top of the shaft.

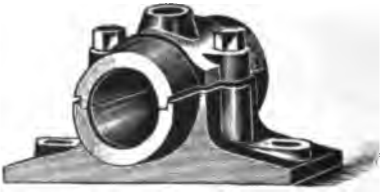


Fig. 352.

An intermediate class is the *sight feed lubricator,* in which the oil is visibly supplied to each bearing from a central reservoir.

Bearings run with much less friction when the oil is freely supplied so as to form an oil bath around the journal; provision should be made of "save-alls" and drip-cups to collect the excess oil.

Where the bearings can be supported on a beam or pedestal, or the shaft is at a low level, other types of bearing-box can be used. The *pillow* or *plummer* block seen in Fig. 352 affords a good substantial support, but it belongs to the second type, of non-automatic adjustment, and needs careful fitting.

Wall-boxes, as in Fig. 353, are necessary where a shaft pierces a wall, being simply a cast-iron frame to stay the opening and reinforce the brickwork. The type illustrated affords good provision for holding and aligning its pillow-block, which is provided with a ball-and-socket-joint. The interior of the keep and of the seat is bored out to a spherical form to receive the ball formed on the halves of the bearing-box proper.

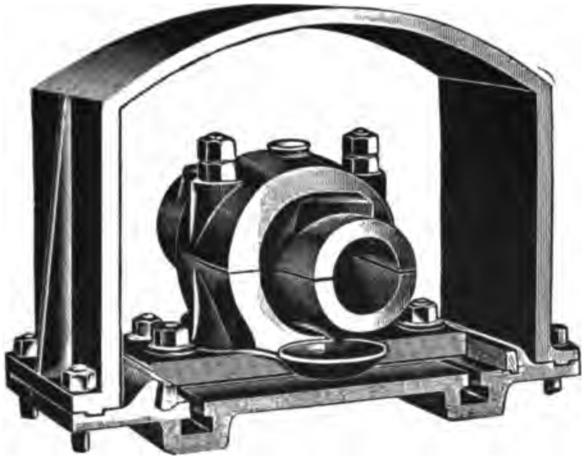


FIG. 353

Where a steam engine has an over-hung crank, the far end of the shaft is frequently supported by a wall box, and the provision of a substantial self-adjusting bearing, such as illustrated in Fig. 353, tends to promote easy running, and provide for any errors in alignment occasioned by unequal settling of the wall and of the engine foundations.

With lighter shafts, an *inverted hanger*, such as is shown in Fig. 354, is often used. This possesses adjustment in a vertical line, but

PEDESTALS.

non-automatic. The term *floor stand* or *pedestal* is also frequently applied to this class of support, which often becomes very large and provided with a heavy pillow-block. When, as is often the case, adjustable wedges are interposed between the pillow-block and the pedestal, with side-wedges, as seen in the illustration of the wall-box, the elasticity with which a good hanger accommodates itself to shaft conditions is more than equalled.

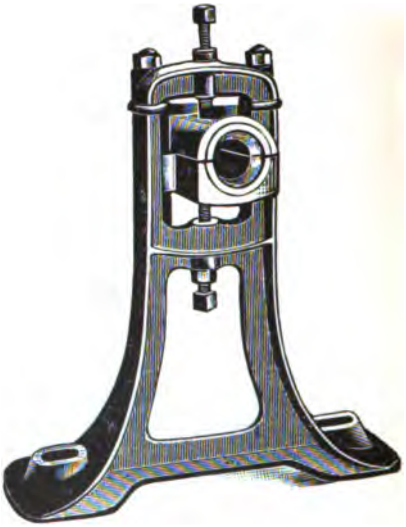


Fig. 354.

Two types of *foot-steps* or bearings for the end of vertical shafts are illustrated. That in Fig 355 is of the plain non-adjustable type, while the other, Fig. 356, is adjustable in every direction. The step is best when bored out to a curve of a parabolic form, as the pressure is then equal in every

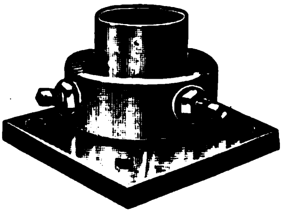


Fig. 356.

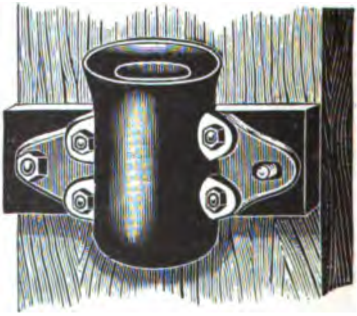


Fig. 355.

direction. Light cast iron hangers, which are too weak for heavy shafts with many pulleys, may be strengthened by making a yoke of steel rods and plates, as illustrated in Fig. 357, and fitting them to the support.

COUPLINGS.

A line of shafting, which is longer than about twenty-four feet, is made up of several lengths. These may be of the same size, or, as is frequently the case, the cross-section of the shaft is diminished as it gets further away from the driving pulley and less power has to be transmitted.

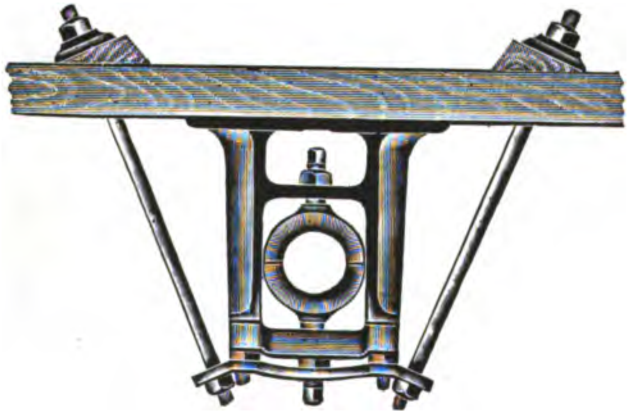


Fig. 357.

It is necessary to connect these different sections and a great variety of devices are in use, which may be classified in three types:—Those meant to be rigid and permanent; others which permit of flexibility in the connection; and a third, which may be coupled or uncoupled at will.

The first class is represented by Fig. 358 which illustrates a *cast iron flanged coupling*, intended as an inexpensive substitute

UNIVERSAL COUPLINGS.

for the solid couplings forged on an engine or prime mover shaft. Each flange is rigidly keyed to its shaft, not infrequently being re-faced in the lathe subsequent to this operation, and the pair bolted together to make the connection. It is usual to make the flanges of each length male and female, *or spigot and faucet*, to preserve the alignment.

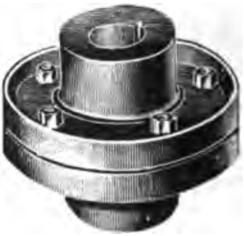


Fig. 358.

The *solid-sleeve coupling*, illustrated in Fig. 359, is used for connecting lengths of shafting of uniform size, as is also the *ribbed compression coupling*, shown in Fig. 360. This latter is a more convenient type, being easily taken apart. It will be noticed that provision has been made with each type for concealment of dangerous set-screws and bolt heads.

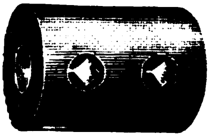


Fig. 359.

Chief in the second class of coupling comes the *universal coupling*, the construction of which is essentially that of two forks pivoted to a cross. This permits of transmission of motion between two shafts inclined towards each other. Wherever the two shafts are parallel, but much out of line, two universal joints similarly arranged to Fig. 361 must be applied.

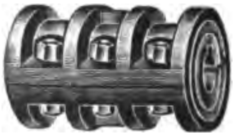


Fig. 360.

Of the third class there are two varieties, the *friction clutch*, one example of which is shown in Fig. 340, and the *jaw clutch*, as seen in Fig. 362. The former is made in a great variety of types, all being on the same principle, namely, the transmission of power from one shaft to another through the frictional contact of parts held together under pressure.

Various surfaces are utilized for obtaining friction, as cast iron on cast iron, or either wood or paper upon iron. The surfaces are generally held in contact by a system of knuckle or toggle joints, or may consist of internal and external cones forced together by levers. The arrangement is such that when the clutch is "thrown in," it will remain in that position without holding, until it is desired once more to throw the parts out of contact.

Jaw or tooth clutches require no special explanation; the principle being simply the meshing of the teeth with one another.

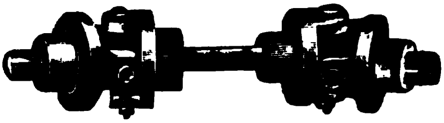


Fig. 361.

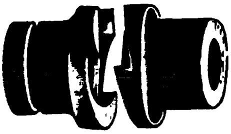


Fig. 362.

It is a difficult matter to throw a jaw clutch in and out of gear while running, so the spiral teeth of the illustrated example are so formed as to remedy this defect in a measure. Still it is always safer to stop the shaft when connecting or disconnecting.

In the course of various erecting operations it becomes frequently necessary to drill many holes, or to tap the same. As it is clearly impossible, or at any rate impracticable, to take the assembled engine, boiler or other machine to the drill-press, various means are used to bring the drill-press nearer. To that end ratchet drills, as previously illustrated in Figs. 157-162, have

FLEXIBLE SHAFTS.

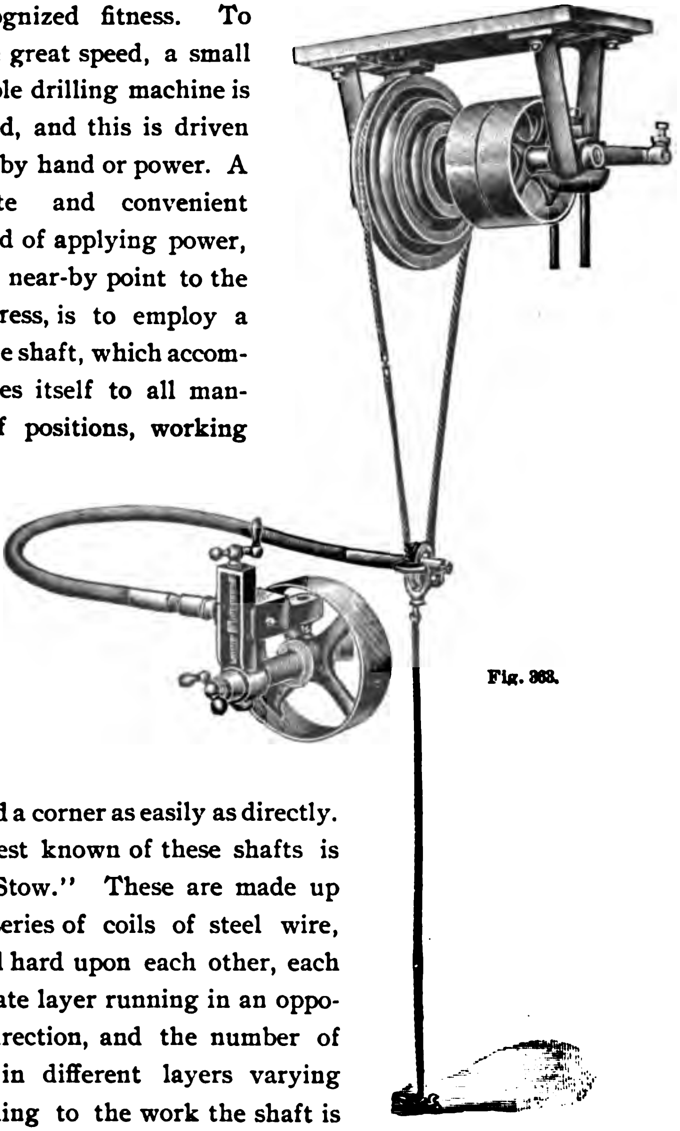


Fig. 363.

a recognized fitness. To secure great speed, a small portable drilling machine is utilized, and this is driven either by hand or power. A favorite and convenient method of applying power, from a near-by point to the drill-press, is to employ a flexible shaft, which accommodates itself to all manner of positions, working around a corner as easily as directly. The best known of these shafts is the "Stow." These are made up of a series of coils of steel wire, wound hard upon each other, each alternate layer running in an opposite direction, and the number of wires in different layers varying according to the work the shaft is adapted to; on being brought to size, about one inch at each end of the shaft is brazed solid, and to these solid ends the fittings are attached, the one to receive the tools to be operated, the other to receive the power from the pulley enclosing it, which in turn receives its power from a belt. Next a case is prepared consisting of a single coil of special square steel wire, its internal diameter being a loose fit for the outside of shaft; this is covered with some flexible material, leather preferably, over which at either end a ferrule is fastened; into this ferrule at one end is screwed the hand piece; at the opposite end the frame which carries the pulley. An inspection of Fig. 363 will show the method of application of this shaft to drilling set-screw holes in a pulley-boss. A cotton rope running over grooved speed-cones transmits power from the countershaft to the pulley upon the flexible shaft.

Other modifications of the same idea will readily suggest themselves; the cotton rope may run in a loop over a series of guide pulleys, balanced by a counterweight, which automatically maintains the tension as the flexible shaft is brought near to, or taken further from, the source of power in its employment.

NOTE—An interesting feature of modern operations is the application of portable tools driven directly by electricity or compressed air. Thus, in a ship yard, a small electric drilling machine is much used. They can be slung over the hull from a travelling crane or gantry, the operator seated upon his machine, and the turning of a switch electrifies four magnets, which attach the apparatus to the ship's side without staging or lashing. A second switch controls the motor driving the drill, and still a third regulates a lamp. On the other hand, a hose for *compressed air* can be led through sinuous passages without the dangers attendant upon electricity, and the small air-driven drill is extremely portable, standing rougher usage than an electro-motor.

BELT PULLEYS.

A pulley is one of the elementary mechanical powers; in a belt pulley the gain is wholly in being able to change the direction of the force. A pulley that imparts motion to the belt enveloping or partly enveloping it is termed a driving pulley or *driver*. A driven pulley is one that receives motion from, or is driven by, the belt; hence in every pair of pulleys connected by belt, one is termed the driver and the other the driven. A *wide-faced* pulley is often both a driving and a driven pulley. *The revolutions of two pulleys connected by belt will vary in the same proportion as their diameters, although their rim velocity will be equal.*

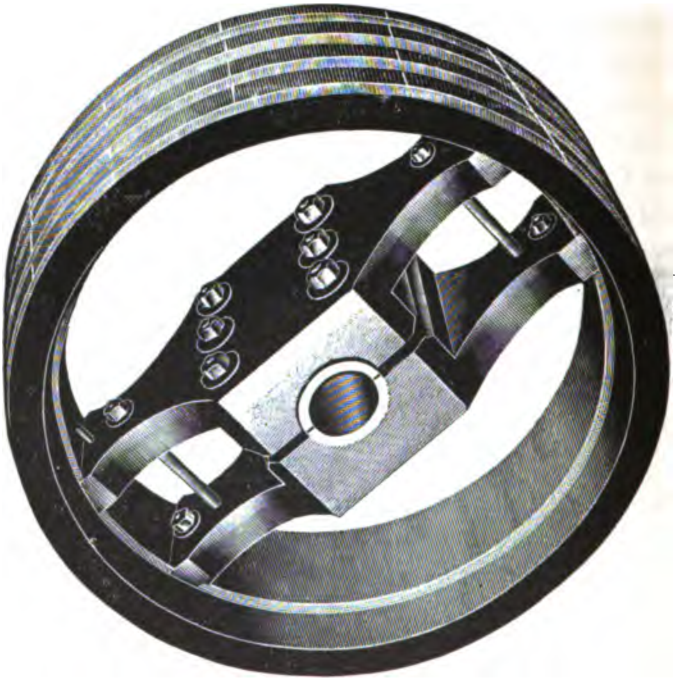


Fig. 364.

BELT PULLEYS.

Pulleys are weaker in proportion to their duty as the speed at which they rotate is increased, because the centrifugal force generated by the rotation acts in a direction to burst the pulley, so that if the speed be continuously increased a point will ultimately be reached at which the centrifugal force will be sufficient to cause the wheel to fly apart. But the speed at which pulleys are usually run is so far within the limits of their strength, that the element of centrifugal force is of no practical importance except in the case of very large pulleys.

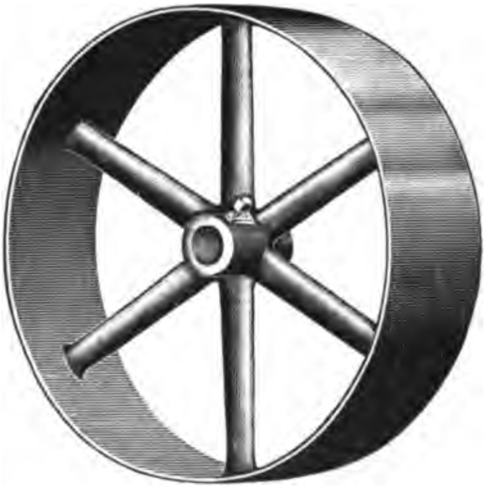


Fig. 365.

All pulleys should be carefully centred and balanced. Driving pulleys on which are run shifting belts should have flat surfaces; all others should be made crowning. Increasing the diameters of pulleys increases the belt speed, and therefore increases driving capacity of belts. Advantage may be taken of this fact, by substituting a larger set of driven and driving pulleys, with the same proportions between them as those they displace. The power transmitted will thus be augmented, while the revolutions of both shafts will remain the same.

FAST AND LOOSE PULLEYS.

To pull is defined to draw or try to draw forcibly or with effort; to drag, to haul, to tug: opposed to push—hence pulley. The office of a pulley in connection with a belt is to drag or to pull with force.

Pulleys are named from their construction or the uses to which they are applied; *compound* pulleys comprise a system of pulleys by which the power to raise heavy weights or overcome resistances is gained at the expense of velocity.

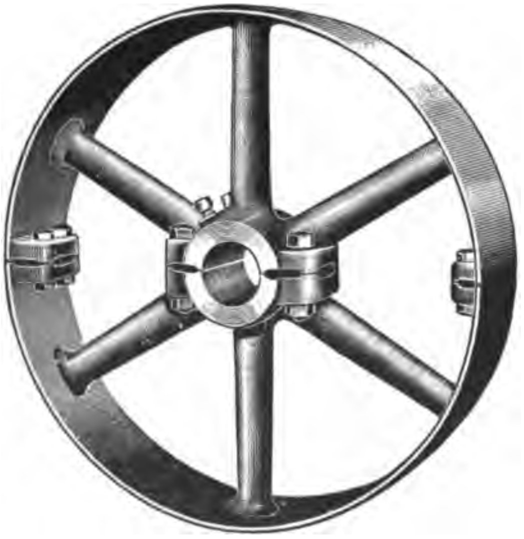


Fig. 366.

A *cone pulley* is a conical one, usually stepped to different diameters; a *crowning* pulley is a pulley with a convex rim, much used where for various causes belts are in danger of slipping off; a *loose* pulley is a pulley fitted loosely on a shaft and placed near a fast pulley, *i. e.*, one fastened to the shaft, to receive and support the belt when it is thrown off in order to disconnect the shaft. It is practically an idle wheel and is often called a *dead pulley*.

A *double-speed* pulley is a combination of two loose pulleys and toothed gearing with one fast-driven pulley, whereby two different speeds of rotation may be obtained with pulleys of the

WOOD PULLEYS.

same diameter by shifting the band from the fast pulley to one of the loose pulleys; it is also called *two-speed* pulley.

A *sliding* pulley is a pulley with a clutch mechanism placed so as to slide backward and forward on a shaft; it is used for coupling and disengaging machinery. A *flanged* pulley is one made with flanges on the side to prevent the belt from working off.

In erecting work, and frequently in long-established plants, a temporary pulley made of wood becomes a vital necessity in order to change the motion of a machine or to temporarily replace a broken pulley.

The millwright's utmost skill and ingenuity comes into play in building up such pulleys from wooden segments.

A pulley of this description is shown in Fig. 364, page 332; this represents what may be called a stock pulley.

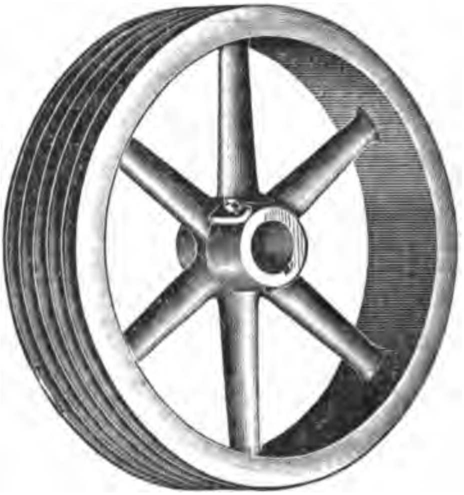


Fig. 367.

The extensive use of wood pulleys is induced by the ease with which a large assortment of them can be carried and thus orders can be quickly filled for almost any description.

Wood pulleys are made with interchangeable bushings so that they can be used within certain limits on different sizes of shafts; they are almost always made split so that they can be easily placed on a shaft without taking it down or moving other pulleys.

SPLIT PULLEYS.

The chief objection to wood pulleys, as compared with cast iron, is that all wood pulleys are necessarily made of built-up segments which are glued together, and, under the action of varying temperatures and different degrees of moisture in the atmosphere, these joints may, where the service is severe, come apart and the pulley fall to pieces. But in ordinary situations this objection has not been a serious one.

Wooden pulleys, when new, grip the belting with nearly twice the friction of iron, but they soon wear smooth and polished, and this advantage disappears.

Fig. 365 represents a solid pulley, the tapered arms, meeting the rim in a slightly rounded corner or fillet, and the rim being thickened at and towards its centre. When the width of rim is excessive in proportion to one set of arms, a double set is employed. In some forms of pulley the arms and hub are cast in one piece and the rim is formed of a band of wrought iron riveted to the arms. By this means shrinkage strains are eliminated and a strong and light pulley is obtained.

Fig. 366 represents a split pulley in which the two halves are bolted together after being placed on the shaft.

Fig. 367 shows a *grooved* pulley, the face of the pulley being ridged to fit the appropriate size of rope in what is called the rope drive, each groove partially encircling an independent rope.

Wood and iron pulleys afford the best results when clothed with leather; this is fastened to the face of the pulley by various ways. The best method is to cement a smooth leather covering upon the pulley, hair-side outwards. The leather should be uniform in thickness, of the width of the pulley face, and of a length equal to the circumference plus the amount of lap, and *minus ¾" for each foot of diameter of pulley.* The lap should be carefully scarfed so as not to raise a hump on the rim, and with the point of the scarf lying in the direction opposite to that in which the pulley revolves.

The belt may be cemented either upon the pulley, or else formed into a ring beforehand, drawn on by means of iron hooks, and then secured with copper bolts or rivets, the heads of which are sunk below the driving surface.

RULES FOR DETERMINING SIZE AND SPEED OF PULLEYS OR GEARS.

If the number of *teeth* in *gears* is used instead of diameter, in these calculations, *number of teeth* must be substituted wherever diameter occurs.

To determine the diameter of Driver—the diameter of the Driven and its revolutions and also revolutions of Driver being given. Diameter of Driven × Revolutions of Driven ÷ Revolutions of Driver=Diameter of Driver.

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BALANCING PULLEYS.

Great caution should be exercised by the erector in assuring himself that all pulleys used on the job are in both *running and standing balance.* In many cases of installation of machinery, vexatious failure and expense has been encountered from lack of this precaution. But, fortunately, pulleys are mostly made by reputable firms who are careful.

A pulley (more especially those running at high speed) should be balanced or in balance when rotating *at the greatest speed at which it is intended to run.* This is necessary, because if the centrifugal force generated by the pulley's rotation be greater on one side than on another, it will cause the pulley shaft to vibrate and shake whenever the amount of unbalanced centrifugal force becomes, on account of the speed of rotation, sufficient to bend the shaft or deflect the framing holding the shaft. Two methods of testing the balance of a pulley are employed: first, *the standing;* and second, *the running balance.*

A standing balance does not balance a pulley, but merely corrects the want of balance to a limited degree. A running balance correctly balances a pulley when running up to the speed at which the balance was made, but *does not balance for greater speeds.*

A standing balance is effected when, the shaft being supported horizontally and with as little friction as possible, the pulley will remain at rest in any position in which it can be placed. A common method of balancing is to set the pulley in slow rotation several times in succession, and if the same part of the pulley's circumference comes to rest in each case at the bottom then it is heaviest and its weight must be reduced, or weight must be added on the opposite side of the pulley.

NOTE.—A pulley that is in balance thus tested, may not, however, be in balance when rotated, or, as already stated, a standing balance may not be a running balance.

PIPES AND JOINTINGS.

The original *pipe* was a hollow reed used for various domestic purposes such as smoking, or as a blowpipe through which the savage might kill his game. In mechanics, the word is defined as a series of tubes for conveying fluid; as a drain-pipe, water pipe, oil pipe, steam pipe, etc. Piping is made up of wood, cement, iron and steel—cast and drawn—copper and lead.

A *joint* in pipe fitting is the place or point where two or more pipes are joined together. The accuracy with which joints are made is next in importance, if not more important, than the strength, durability and quality of the pipes themselves.

The correct arrangement of the piping with its jointings in any plant, whether the pipe is to be used for conveying gas, steam, ammonia, oil, sewage, smoke—as the fire tubes of a horizontal boiler—contributes often more to its successful working than any other part or parts of the mechanism.

The first duty of an erector or engineer is to become familar with the location, intended use and the conditions of the pipe system of a plant, whether water, steam or manufacturing works. This remark especially applies to a man taking a responsible position in a new place, such as an absorption refrigerating plant where the whole system is composed of piping with its extra strong jointing.

It is in the piping that the artisan has an opportunity of showing his skill in accomplishing work that is seldom described in books, a knowledge which passes from one craftsman to another in such a manner as to form the basis of successful co-operation into societies for mutual benefit. The subject is such that the following pages should be considered as mainly suggestive.

PIPES AND JOINTINGS.

Standard sizes of pipe threads adopted by the Manufacturers' Association, for various common sizes of pipe, are shown in the following illustrations, Figs. 368-372. Figured dimensions are added so that the form given to the thread may be seen.

The angle of a standard pipe thread is 60°, and it is slightly rounded off at top and bottom of thread, a very necessary precaution in practical work. This makes the depth of the thread equal to four-fifths of the pitch, or 0.8, instead of 0.866, as would be the case with full V-thread with 60° angle between its sides.

Taking the first illustration, Fig. 368, which represents a section of the thread on a 2-inch pipe;—it will be noticed that the perfect or full thread extends back from the end of the pipe for 0.58 inch, of course tapering at the standard rate of ¾ inch per foot. Next, for a length of 0.174 inch the thread remains sharp at the bottom, slightly flattening at the point; while, in the remaining 0.348 inch the thread "runs off to nothing." The total length of screwed portion is thus 1.102 inches.

Similarly, in the succeeding sections, it will be seen how there are, with each pipe, three stages of thread:—(*a*), Perfect and full thread, (*b*), thread sharp at bottom and slightly flat over top, and (*c*), the rapid tapering of the imperfect thread until it has attained the full external diameter of the pipe.

Fig. 369 shows the standard sizes of 3-inch tube, while those for 4-inch are exemplified by Fig. 370; the dimensions of thread for 5-inch tubes are given in Fig. 371, and the same particulars for 6-inch will be found in Fig. 372. In making taps or dies of correct form, it is only necessary to know the rate of taper,

STANDARD SIZES OF PIPE THREADS.

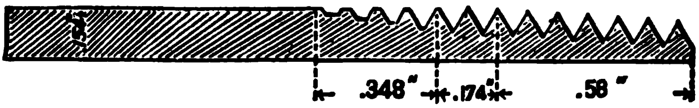

Fig. 368.

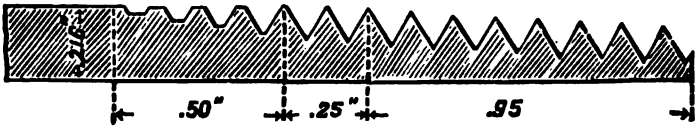

Fig. 369.

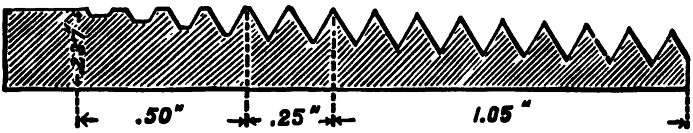

Fig. 370.

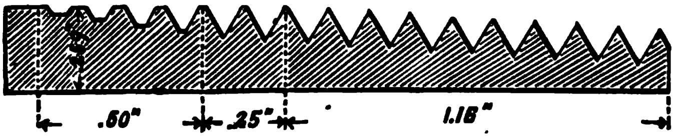

Fig. 371.

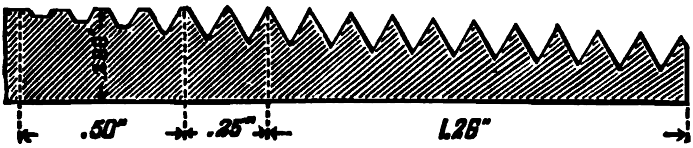

Fig. 372.

length of full-threaded or perfect portion, and the sizes at bottom and top of thread at the end of the pipe. These have been given in the table, and are taken from authoritative sources.

The length of the imperfect portion of the thread has no effect upon the standard, nor the depth to which the tap may be run into the fitting beyond the point at which the size is given, or, stated differently, beyond the end of the pipe. Attention being given solely to the points previously enumerated, a correct and standard thread may be secured.

TABLE OF DIMENSIONS OF PIPE THREADS.

Nominal Bore ins.	No. of Threads per in.	Thread at end of pipe.		Length of Perfect Thread ins.	Nominal Bore ins.	No. of Threads per in.	Thread at end of pipe.		Length of Perfect Thread ins.
		D. at Bottom ins.	D. over Top ins.				D. at Bottom ins.	D. over Top ins.	
⅛	27	.334	.393	.19	3½	8	3.738	3.938	1.00
¼	18	.433	.522	.29	4	8	4.234	4.434	1.05
⅜	18	.568	.658	.30	4½	8	4.731	4.931	1.10
½	14	.701	.815	.39	5	8	5.290	5.490	1.16
¾	14	.911	1.025	.40	6	8	6.346	6.546	1.26
1	11½	1.144	1.283	.51	7	8	7.340	7.540	1.36
1¼	11½	1.488	1.627	.54	8	8	8.324	8.534	1.46
1½	11½	1.727	1.866	.55	9	8	9.327	9.527	1.57
2	11½	2.223	2.339	.58	10	8	10.445	10.645	1.68
2½	8	2.620	2.820	.89	11	8	11.439	11.639	1.78
3	8	3.241	3.441	.95	12	8	12.433	12.633	1.88

The taper given to conical tube ends equals ¾ inch per foot of length, or an inclination of 1 in 32 to the axis of the tube.

PIPING TOOLS.

The tools used in pipe fitting are too numerous to describe in this volume; much ingenuity is used in devising new and special tools for cutting, threading and manipulating pipes and fittings. The *steam fittings* themselves, such as elbows, nipples, bushings, ells, tees, plugs and various kinds of couplings, would cover many pages, hence the following illustrations and descriptive matter are only a beginning to what the erector and engineer need to know much more of.

Sizes of pipe-taps, and pipe fittings are based upon the *nominal bore of the pipe.* Thus a ½-inch pipe-tap is suitable for the outside of a so-called ½-inch pipe, which really measures in fact about 27/32 in. on the outside, and about 9/16 in. on the inside. Taps and reamers are usually tapered ¾ inch to the foot, the standard pipe taper.

Expanding die stocks are preferable to the solid dies, as they save time used in filing the end of the pipe. They are easily adjusted; and by means of a spring gauge can be opened and removed from the pipe instead of turning back. The dies can be resharpened.

Gas-pliers, a useful combination tool for pipe fitters, is shown in Fig. 373, having serrated jaws for gripping, in the larger opening, small gas pipe; in the smaller, gas nipples or burners; in the tip of the jaws, small screws or parts of gas fittings; whilst one shank is formed as a screw-driver.

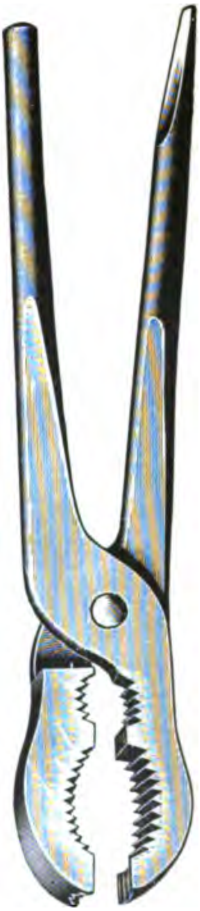

Fig. 373.

PIPE CUTTERS.

For cutting small size pipes, the *Saunders' cutter*, Fig. 374, has proved serviceable; it has a cutting wheel, with two rollers to support the tool and the pipe and keep it in its proper position, thus minimizing the danger of breaking the rotary cutter.

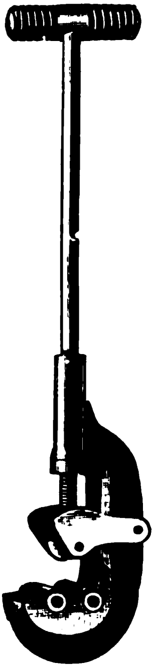
Fig. 374.

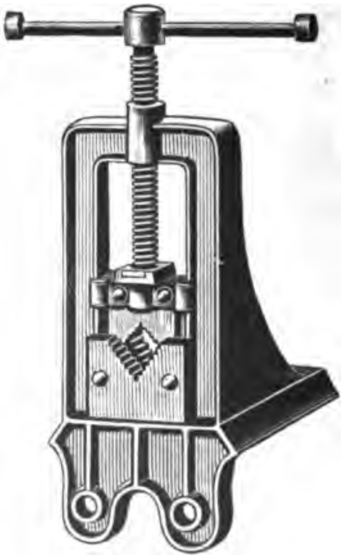
Fig. 375.

For outside jobs, *a portable pipe vise*, as Fig. 375, is of great utility. With the type shown, the framing is of malleable cast iron, thus preventing it from cracking under strains or jars.

In connecting together different sized threads, the *bushing*, Fig. 376, is used when it is desired to insert a small fitting in a large orifice.

PIPE SOCKETS AND COUPLINGS.

The *reducing socket* or *coupling*, Fig. 377, is employed to unite two pipes of different diameters.

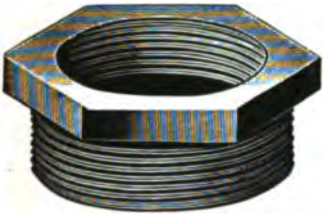

Fig. 376.

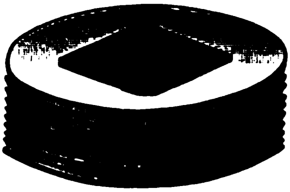

Fig. 379.

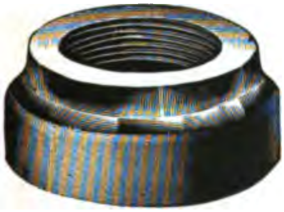

Fig. 377.

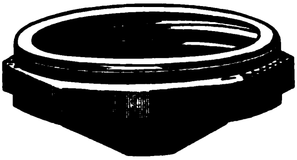

Fig. 380.

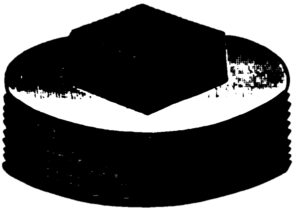

Fig. 378.

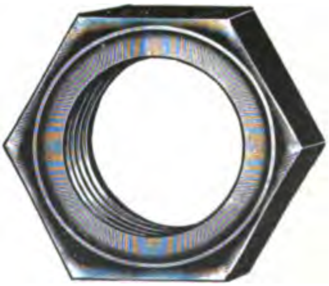

Fig. 381.

For closing pipes, various means are adopted; the simple *plug*, Fig. 378, or the *socket plug*, Fig. 379. which screws in flush

PIPE UNIONS.

with the end of the pipe, or again, the *cap*, Fig. 380, which is intended for use where the pipe-end has to be opened for inspection, etc.

Lock nuts, as Fig. 381, are used to lock fittings or couplings on the pipes, so that vibration, etc., shall not cause them to slacken.

Lip unions, as seen in perspective in Fig. 382 and in section in Fig. 383, are commonly used to connect smaller sizes of pipe. The small drain, gauge and oil pipes, etc., about an engine-room are connected by this type of joint, as it is easily disconnected and as readily put together again.

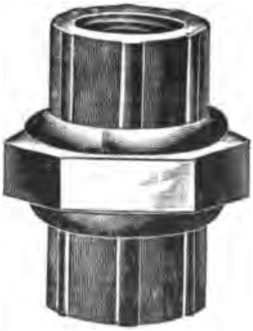

Fig. 382.

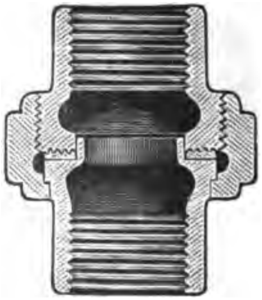

Fig. 383.

Provision has to be made for expansion and contraction, as explained in the foot-note, or else the pipe would have to spring to accommodate the increase in length, with risk of leaky joints and possible damage to its supports, besides the danger of serious accident. A *slip expansion joint*, as illustrated in Fig. 384, is a customary fitting for this purpose.

EXPANSION JOINT.

The flange at either end is secured to others in the line of piping in which it is inserted, and the turned brass sleeve, on the right hand of the figure, slides out and in the stuffing box of the other part as the length increases or decreases with variation of temperature.

A gland ring, also shown in the illustration, serves to retain the packing in the stuffing box, while the gland studs are prolonged through clearance holes in the sleeve flange to act as preventers and prevent the loose piece from being blown out.

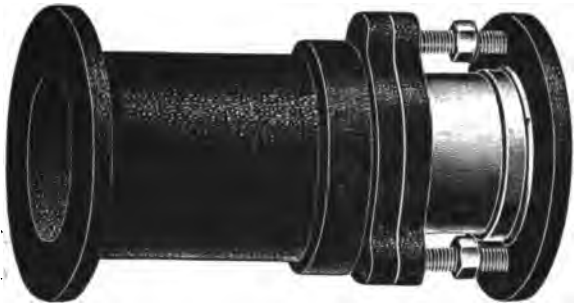

Fig. 384.

A provision for expansion may be made by combining elbows and bends together so as to form a U in the pipe; this will frequently give relief, but is liable to leak around the screw threads; hence a better plan is to use *a copper pipe bent to a U-shape* with a good radius at the corners. This will have all the advantages of a slip joint.

NOTE.—As has been previously stated, steel and wrought iron expand 6¼ inches per million, for each degree of Fahrenheit scale of increase in temperature, cast iron expanding 6 inches and drawn copper 9 inches per million for the same rate of increase. A steam pipe, carrying 120 lbs. steam, corresponding to 350° Fahrenheit and 200 feet long, will thus be nearly 4½ inches longer when exposed to steam than when cold.

SPIRAL-RIVETED PIPE.

In manipulating large stop-valves extreme care is necessary not to damage the pipe by sudden opening of the valve, nor to injure the valve by shock, upon quickly closing it and arresting the flow of the fluid. With important valves it is becoming customary to fit a *pilot valve*, as shown in Fig. 385, where the smaller valve is used to place the large main valve in equilibrium either for opening or closing.

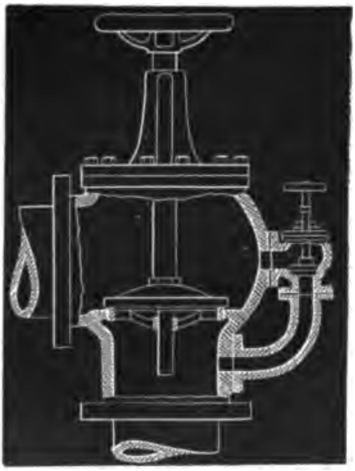

Fig. 385.

The spirally-riveted pipe, Fig. 386, is claimed to be stiffer than one with a longitudinal joint; certainly the strains upon the rivets are much less than in the latter case, and single riveting can be employed instead of double, while the covering plate or butt strap is dispensed with.

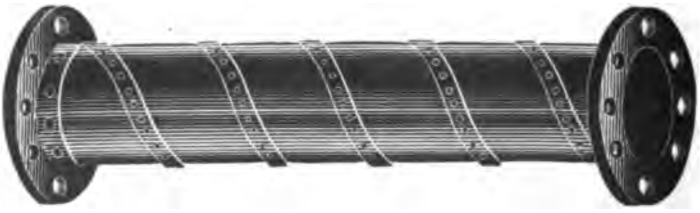

Fig. 386.

NOTE.—*In taking old pipe down* a refractory joint may be sometimes loosened by striking it with a hammer while it is under full pipe tongs pressure; or these means failing, the elbow or tee may be heated, which should be done as quickly as possible, so that the fitting may be hotter than the pipe A very good method of doing this, where it is desired to save the fitting, it is to pour red-hot lead over it.

SPIRAL-RIVETED PIPE.

With steel steam pipes of large diameter it is customary to use riveted joints instead of lap-welded ones. Some owners specify an external butt or welt strap to be single-riveted over the weld when a pipe is used for pressures over 200 lbs., but the more general practice is to rely upon the riveting alone for the strength of the joint.

LIST OF SIZES OF GALVANIZED, SPIRAL-RIVETED FLANGED PIPE.

Made of galvanized iron, and re-galvanized after formation, thus rendering all laps and seams solid. Each length is tested to 150 lbs. hydraulic pressure.

Bore of Pipe. Inches.	Thickness.		Weight Per Foot Run.	Bore of Pipe. Inches.	Thickness.		Weight Per Foot Run.
	B. W. G.	Inches.			B. W. G.	Inches.	
3	No. 20	.0355	2¼ lbs.	12	No. 16	.065	14 lbs.
4	"	"	3 "	13	"	"	15 "
5	"	"	4 "	14	No 14	.083	20 "
6	No. 18	.049	5 "	15	"	"	22 "
7	"	"	6 "	16	"	"	24 "
8	"	"	7 "	18	"	"	29 "
9	"	"	8 "	20	"	"	34 "
10	No. 16	.065	11 "	22	No. 12	.109	40 "
11	"	"	12 "	24	"	"	50 "

These pipes are made in lengths up to twenty feet, and can be supplied to drawings, but in that case, any length under five feet is charged as being five feet long.

When pipes are to be taken down and re-erected elsewhere they should be marked to their fittings and places before being taken down, as this will preserve their lengths for re-erection. Black japan is an excellent marking for this purpose because it dries quickly.

PIPE CLAMPS.

The liability to leakage of screwed pipe joints has already been mentioned. These leaks are apt to develop at any time, and it is often absolutely impracticable to shut off the pressure to repair the defect. To enable immediate repairs to be made in such cases, there has arisen a class of devices known as pipe joint clamps.

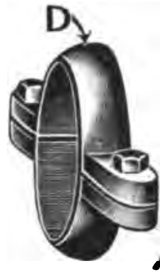

Fig. 387.

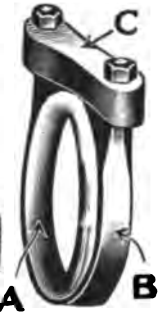

Fig. 388.

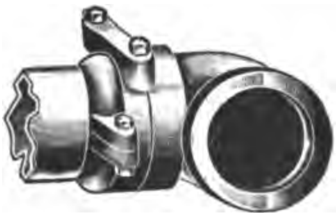

Fig. 38.

A simple form of pipe clamp is illustrated in Figs. 387-389. The packing ring A, Fig. 388, is placed around the pipe, against the elbow or tee in which the leak has occurred. Then the flexible U-shaped band B is placed over it. The ends of this strap are threaded, and are passed upward through the yoke C, which is pressed down on the packing ring. The nuts are next put on, and screwed up just enough to hold the packing in place. The split collar D, shown in Fig. 387, is next firmly clamped around the pipe, against the packing. Finally, the nuts on the strap ends are tightened, and the packing, compressed between

---

NOTE.—The profession most nearly related to that of steam engineers is the working steam fitters' occupation. Strictly speaking, the engineer should produce the steam, and it is the steam fitters' place to fix up all the steam pipes and make all the necessary connections; but where the steam plants are small, the engineer may be steam fitter also; hence the introduction in this work of many points which are necessary to be known.

DETAIL OF PIPE CLAMP.

the yoke, the strap and the pipe, and being unable to expand on the side next the collar D, is forced into the angle between the pipe and the edge of the fitting, making a perfect seal.

The appearance of the completed clamp is well shown in Fig. 389, where it is seen in use on an elbow connection.

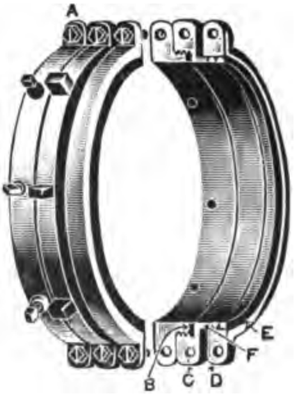

Fig. 390.

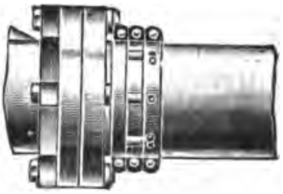
Fig. 391.

Another more elaborate form is illustrated in Fig. 390, in which there are three rings, made in halves and held together by screws. The first, A, is firmly clamped to the pipe by means of the set screws spaced at equal distances around it. It has a threaded lip B, which engages with the threaded portion of the collar C. Both A and C are of such internal diameter as to fit snugly to the pipe. The collar D is considerably larger inside, and contains a ring of packing E between itself and the pipe flange. The collar A being held tightly by the set screws, and the ring C being turned by means of a spanner, the lug F forces the packing toward the flange. Since the

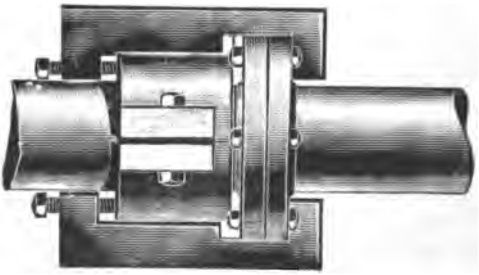
Fig. 392.

BOILER PIPING.

collar D prevents the packing from expanding, it is forced firmly against the pipe fitting and effectually stops the leak.

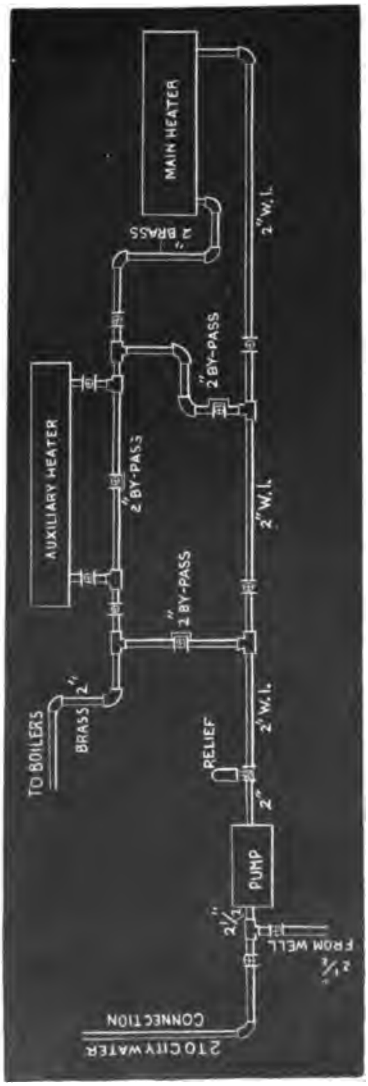

Fig. 393.

The assembled clamp is seen in position in Fig. 391.

Where a flange joint is employed and a leak occurs between the pipe and the flange, the arrangement shown in Fig. 392 may be used to advantage. A collar made in halves is put in place on the pipe, close to the flange.

A piece of sheet rubber is held between it and the pipe, the rubber projecting a quarter of an inch or more toward the flange, and being flared so as to fully cover the joint. Then three clamps, as seen in the illustration, are put in position and the set screws tightened, forcing the packing hard against the flange, thus preventing further escape of steam.

NOTE.—Whatever the size of the circulating pipes, the supply and drip pipes should be large, to insure good circulation; the drip pipes especially so. This is all the more necessary when the pipes are exposed, or when there is danger of freezing after the steam is shut off.

EXAMPLE OF BOILER PIPING.

The illustration on the opposite page, Fig. 393, is a reproduction of a blue print showing a system of piping. It is included as an example of an installation. It shows the connections between a battery of boilers and its water supply.

The valves used in the several lines are represented by the small crossed circles between the flanges attached to the pipe ends. The 2 inch "by-passes," shown in the plan, are similar to the one in section illustrated in Fig. 385, page 348.

It will be noted that brass pipe is called for after the water leaves the heaters—the initials W I stand for wrought iron pipe in use for cold water. The fittings, such as ells, tees, relief-valves, etc., are shown in the drawing in the customary method. It will be noticed that while the supply of water is intended to be drawn from a well by a 2½ inch pipe, a connection is also made with the city water through a 2 inch pipe so that the latter may be used in case of need.

Supply-pipes.—These may be of lead, brass, galvanized iron, tin-lined lead, or block tin. Lead pipe is easily bent to suit any position and is more durable underground than galvanized-iron pipe. The grade known as A or "strong" is the lightest that should ordinarily be used, and if there is considerable pressure from the city mains extra strong pipe should be employed.

Tin-lined iron pipe, which is made by pouring tin into a wrought-iron pipe, possesses several important advantages. Neither hot nor cold water will affect the tin lining, so that it may be drawn free from poison or rust. Rats will not gnaw it, and it has too small a scrap value to attract the cupidity of thieves. Its durability is much greater than that of an iron pipe dipped in tin, or of an iron pipe lined with a detachable tin one.

THE STEAM LOOP.

This is an attachment to a steam boiler, designed to return water of condensation. It invariably consists of three parts, viz.: the "riser," the "horizontal" and the "drop leg," and usually of pipes varying in size from three-fourths inch to two inches. Each part has its special and well-defined duties to perform, and their proportions and immediate relations decide and make up the capacity and strength of the system. It is, in fact, nothing but a simple return pipe leading from the source of condensation to the boiler, and, beyond this mere statement, it is hardly possible to explain it; it has, like the injector and the pulsometer pump, been called a paradox.

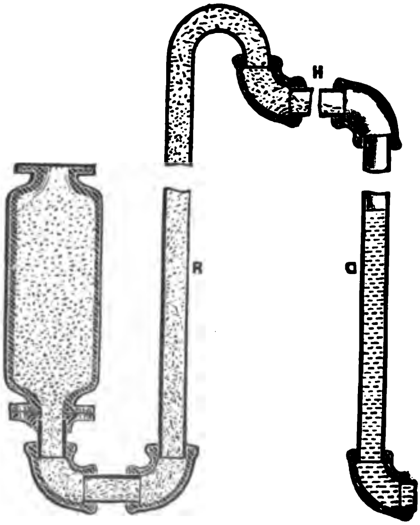

Fig. 394.

The range of application of the steam loop practically covers every requirement for the return of water of condensation. It is much used in connection with steam-heating apparatus.

As the steam loop is merely an arrangement of piping, there are no working parts, and consequently no need of lubrication. Furthermore, there is nothing to wear and get out of order.

NOTE.—*Difference between a cock and valve.*—The cock is a valve, but a valve is not a cock; the cock is a conical plug slotted and fitted with a handle for turning the cone-shaped valve with its opening into or out of line with the opening of the pipe.

STEAM LOOP.

The cost of returning the condensed steam to the boiler is practically nothing compared to the cost of maintenance of the pump. The illustration, Fig. 394, shows the working of the steam loop. It will be noticed that the riser R does not contain a solid body of water, but, on the contrary, a mixture of water and steam. This mixture is readily condensed and the whole converted into water, which process is constantly going on in the horizontal pipe H. The condensation of steam at that point would soon produce a vacuum were it not for the fact that the mixture of steam and water from the riser immediately takes

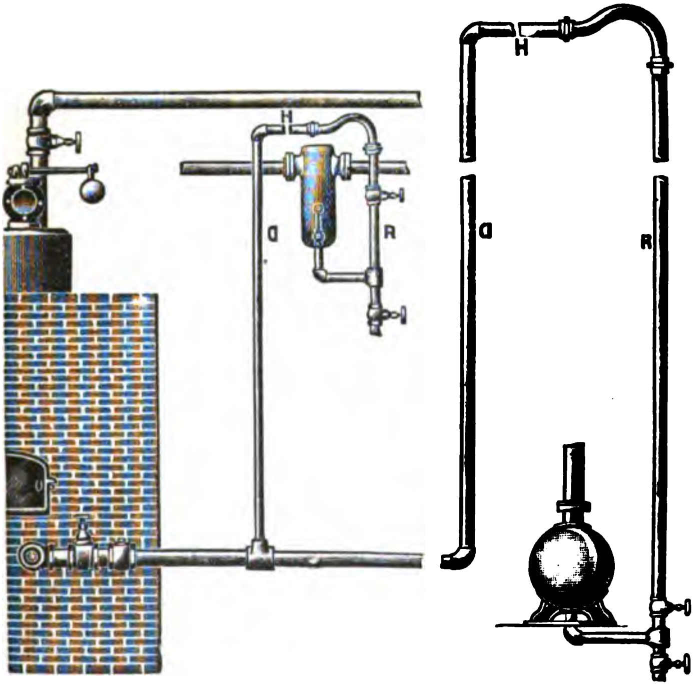

Fig. 395.

STEAM LOOP.

the place of the steam as it condenses. The riser is constantly supplying steam, conveying large quantities of water in the form of a fine spray to take the place of the steam condensed in the horizontal pipe H. As soon as the steam and spray pass the goose-neck section of the horizontal pipe, they cannot return to the riser; hence the contents of the pipes constantly work from the separator towards the boiler.

A drip should be connected with the separator so as to drain the latter and the riser when they become filled with water, as will generally be the case after steam has been shut off for some time and the main piping has become partly filled with accumulated water.

In order to proportion a steam loop properly by calculation, the specific gravity of the mixture in the riser should be ascertained, the difference of pressure between the boiler and the separator, and the pressure under which the system is to work, the latter quantity being used to determine the weight of water at the existing pressure and temperature. (See note.)

The current of steam and spray ascending the riser is due to the lower pressure in the horizontal pipe *h* caused by the condensation of steam, as previously explained. If the difference of pressure between the separator and the pipe is, say, 2 pounds, then it will sustain a column of water at a temperature of 297° F., equal to 2.509 x 2 = 5.018 feet high.

NOTE.—The weight of a cubic foot of water at 60° Fahr. and at the pressure of the atmosphere is 62.3 lbs. Consequently a column of water one inch square and weighing one pound will measure 144 ÷ 62.3, or 2.311 feet in height.

With steam at 50 lbs. pressure, the temperature of the water is 297°, and the weight of a cubic foot is 57.35 lbs.; the height of a column one inch square becomes 144 ÷ 57.35 lbs., or 2.509 feet for each pound weight.

CALCULATING STEAM LOOP.

The riser, R, however, does not contain water alone, but a mixture of steam and water, the specific gravity of which varies, but may be taken as one-fourth that of water, about three-fourths of the volume being assumed to be steam. In that case the column sustained will equal 5.018 x 4 = 20.072 feet. Deducting 10 per cent. for friction, the net height of the riser pipe may be 18 feet.

In the larger illustration, Fig. 395, will be seen two applications of the steam loop; one from a separator on a line of steam piping, to which the previous calculations apply; the other from a radiator which is set below the water level. It is the calculation of this latter condition which most troubles engineers. (See example given in the note.)

As shown previously, 10 per cent. should be added for friction, and it is better to allow 5 feet in any case to provide for it.

NOTE.—Assuming that in this case there is a difference of 5 lbs. pressure between the top and bottom of the riser pipe, and that the lower point in the return system is 12 feet below the water level in the boiler; the same pressures and temperatures as before.

If the loop is full of steam only the water will rise in the drop leg, D, 5 x 2.509 = 12.545 feet to balance the difference in pressure. Adding this height to the required lift, it will be found that the top of the water column should stand 12.545 + 12 = 24.545 feet above the bottom of the riser when the system is in equilibrium. Now, as the mingled water and steam in the riser pipe weighs more than the steam, the pipe must be lengthened still more; assuming the previous specific gravity of one-fourth that of water, this additional height will naturally be 24.545 feet ÷ 3 or 8.182 feet, one-fourth of the extra height being above the present level, and three-fourths below. Adding together 24.545 and 8.182 feet, the result gives 32.727 feet for total height of riser pipe, or subtracting the 12 feet lift, gives 20.727 feet as the height of the drop leg above the water level in the boiler.

SURFACES AND CAPACITIES OF PIPES.

The size of pipes should not exceed 1¼" to 1½", although the horizontal H may be as large as 2½", to facilitate condensation. If the pipes are insufficient, add more pipes rather than increase the bore.

No condensation should take place in the riser pipe, and, it should be carefully clothed, but the horizontal pipe needs only to be protected against freezing.

The presence of air in the loop often leads to failure, and a small cock should be placed at the highest point to expel air when starting, also to be opened at intervals, during continuous working, for a similar purpose.

SURFACES AND CAPACITIES OF PIPES.

SIZES OF PIPES.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	4½ in.	5 in.
1. Outside circumferences of pipes in inches.	2.652	3.299	4.136	5.215	5.969	7.461	9.032	10.99	12.56	14.13	15.70	17.47
2. Length of Pipe in feet to give a square foot of outside surface.........	4.52	3.63	2.90	2.30	2.01	1.61	1.32	1.09	.954	.849	7.63	.686
3. Number of square feet of outside surface in ten lineal feet of pipe....	2.21	2.74	3.44	4.34	4.97	6.21	7.52	9.16	10.44	11.78	13.09	16.56
4. Cubic in. of internal capacity in ten lineal feet of pipe....	36.5	63.9	103.5	179.5	244.5	402.6	573.9	886.6	1186.4	1527.6	1912.6	2398.8
5. Weight in lbs. of water in ten lineal feet of pipe........	1.38	2 31	3 75	6.5	8.8	14.6	20.8	32.1	43.6	55.4	69.3	86.9

Pipe manufactured from double thick iron is called X-strong pipe, and pipe made double the thickness of X-strong is known as XX-strong pipe. Both X-strong and XX-strong pipe are furnished with plain ends—no threads unless specially ordered.

PLUMBING.

Lead working is an ancient art, both in sheets and in pipes. The word plumbing is derived from the Latin word for lead, hence a plumber is a lead worker. Lead is one of the elementary metallic substances; it is used largely in combination with tin, copper, etc., and is the main alloy used in a measure to debase and cheapen nearly all the higher metals, even silver and gold. It is 11.4 times heavier than water, bulk for bulk; lead melts at a temperature of 617° Fahr.

The tenacity of lead is extremely low, in comparison, its tenacity is only one-twentieth that of iron; it is so soft that it may be scratched with the thumb nail. If sufficient heat is applied lead boils and evaporates; it transmits heat very slowly; of seven common metals it is the worst conductor, therefore it is good for hot water pipes. Mixed with quicksilver it remains liquid. An advantage to be found in the use of lead is its durability and comparative freedom from repairs. In London, soil and drain water pipes which have been fixed 300 to 500 years are as good now as the day they were first made.

The processes of lead working are executed by manual dexterity acquired by long practice, and to do the work properly requires special tools. Some of these are used in common with other departments of mechanics, but are none the less necessary in lead working. Among the principal tools are *saws* such as a compass saw and double-edged plumber's saw; *spirit levels*, *looking glasses* used in making underhand joints, etc.; the *plumber's torch*, used also by engineers to explore the interior of boilers and other dark places about the steam plant; *chisels*, such as cape, cold, diamond-nose and wood chisel used in cutting away wood work; the *turnpin*, the wooden cone used to force open the pipe just before jointing; the plumber's *snips*, the plumber's *tap borer or reamer* used for making and enlarging holes; the well-known and always useful *ladle* shown in Fig 399, also the *round-nosed pene* hammer used to force open the lead pipe before jointing.

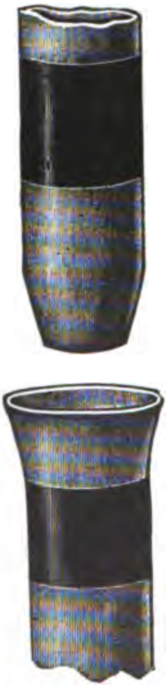

Fig. 396.

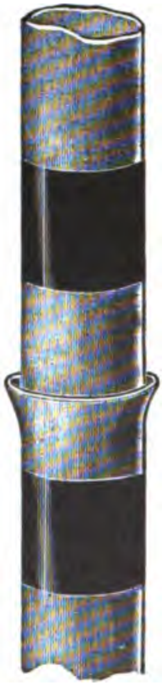

Fig. 397.

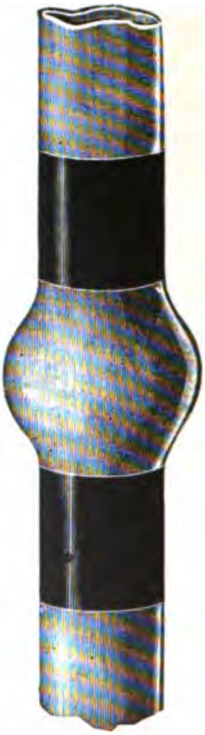

Fig. 398.

In addition to the others the *caulking tool* is used, also a soldering tool known among plumbers as a *copper-pointed bolt.*

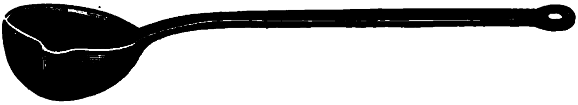

Fig. 899.

THE WIPE JOINT.

A *wiped-joint* is the best known process of jointing lead pipe; other methods are as follows, the *flow joint*, the *ribbon joint*, the *blown joint*, the *astragal joint*, etc.

Generally speaking every erector, millwright and engineer should know how, 1, *to joint lead pipe*—to make a "wipe joint,"—as in a hundred emergencies this knowledge will be of worth; 2, how to make a temporary stopping of leaks; 3, how to bend pipe with sand or springs; 4, how to "back air pipes" from sinks; 5, how to use force pumps; 6, how to arrange the circulating pipes in hot-water boilers; 7, how to make solder; 8, how to repair valves, etc., etc. After learning how to make a "wipe joint" everything is said to be easy relating to the plumber's trade, hence the value of the following practical directions with their several illustrations for accomplishing the desired results.

In preparing lead pipe for jointing, it is usually painted above and below the joint with a mixture of lampblack and size known as plumber's soil to prevent the solder from adhering where it is not wanted; this painting is considered ornamental as may be observed in the illustrations.

NOTE.—This soil is best made in small quantities as required, the lampblack being mixed with sufficient boiling water to dissolve it, and glue or size being added to make a jelly. The soil is usually kept in a small copper can known as the *soil can*, and requires to be heated every time it is applied, so that it will stick to the pipe; it is put on with a small brush.

THE HORIZONTAL WIPE JOINT.

The pipe ends to be united are next sawed squarely across, to make the joints true with the pipe. It is usual to prepare the female end first, i. e. the lower pipe shown in Fig. 396. The end is flared or belled out with a *turnpin*, which is a taper boxwood plug, so that the pipe is enlarged a quarter of an inch. The cup thus formed serves to retain the solder. The internal and external surface must be shaved or scraped bright and clean with a *shave-hook*, a small tool with a heart-shaped blade set at right angles to its stem or handle. Immediately after the parts require to be "touched" or anointed with a little tallow, to preserve them from the oxidizing action of the atmosphere, which would otherwise tarnish the surfaces, and form a film to which the solder cannot adhere.

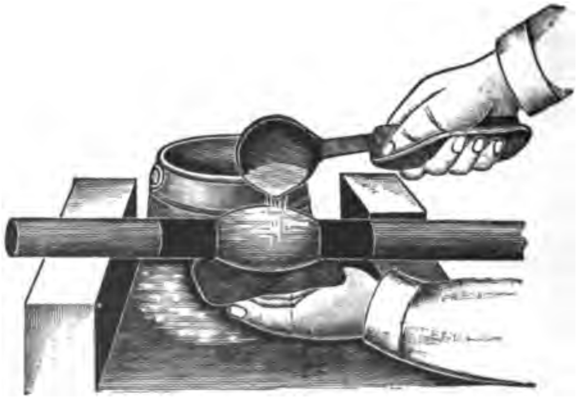

Fig. 400.

The male end of the pipe is tapered off with a rasp, as shown in the upper part of Fig. 396, cleaned with the shave-hook and "touched" as before; the two pieces are brought together as in Fig. 397, and are then ready for the joint.

THE VERTICAL WIPE JOINT.

The *cloth* used for wiping is a pad of moleskin or fustian about four inches square made from a piece twelve inches by nine, folded six times, and sewed to keep it from opening; the side next the pipe is saturated with hot tallow when used.

If the lead has been brought to the heat of the solder, and the latter properly manipulated and shaped while in a semi-fluid or plastic condition, the joint gradually assumes the finished appearances of Fig. 398. Fig. 400 shows the method of wiping a *horizontal joint*, and is an illustration of the preliminary process, while Fig. 401 shows the actual operation of wiping on a *vertical* pipe A small piece of paper is placed under the joint to catch surplus solder, or, as shown in Fig. 401, a lead flange, cut open on one side, is placed around the vertical pipe for the same purpose; this is held in place by twine, and interlocking of the corners, as illustrated. The ladle is taken three parts full of solder, melted and just so hot that the hand can be kept within two inches of its surface. The solder is poured lightly on

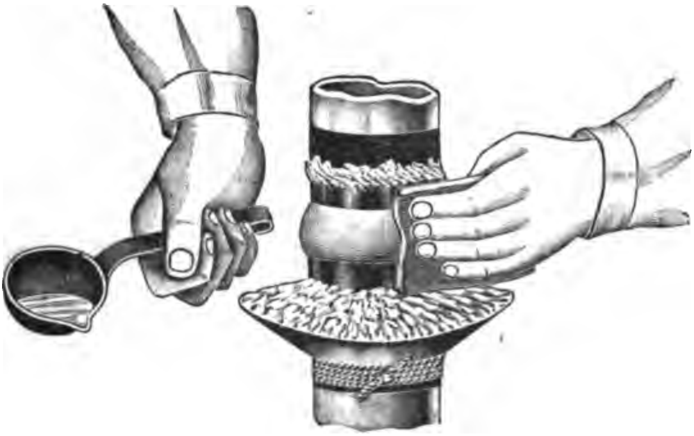

Fig. 401.

SHEET LEAD WORKING.

A *tank* is an artificial receptacle for liquids; a cistern is primarily a reservoir, a natural place containing water—more commonly, it is an underground reservoir or tank.

A *reservoir* is a place where water is collected for use when wanted. A *vat* is a cistern or tub. A *tub* is an open wooden vessel formed with staves, bottom and hoops; a kind of short cask, half barrel or firkin, usually with one head. The foregoing are all at times *lined with sheet lead* in manufacturing operations.

Where a wooden tank is used, the lead sheets are nailed to it with good clout nails at the edges, and fastened in the middle portions by brass screws fitting into a countersink in the wood, to which the lead has been previously dressed. The heads of these screws require to be covered with solder.

The lead lining for an *iron tank* is suspended, if small, by being bent over the flange around the top, but if it is large, it may have to be sustained by countersunk headed bolts through both metals, with the nuts outside, a covering patch being subsequently fitted over the bolt head.

The joints are wiped very much as for a pipe, the soldering being poured from the ladle on the seams, and guided by the *pouring stick*, which is simply a grooved stick to form a channel. The *tank iron*, a large bulb of iron with a bent handle, which is illustrated in Fig. 403, is used to maintain the heat of the solder, *alternate passes with cloth and iron* being made over a length of

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NOTE.—Whenever sulphuric or hydrochloric acids have to be used, the tanks containing them require to be lead lined (nitric acid, on the contrary, must be kept *in iron or stoneware vessels*). It is customary also to line water cisterns, but only when the waters are "hard." Soft water containing much dissolved air becomes dangerously contaminated by the lead held in solution.

LEAD BURNING.

eighteen to twenty inches, the superfluous solder being carried in front of the work.

There is another process of uniting leaden sheets, which is superior to jointing them with solder. This is *lead burning*, sometimes termed the *autogenous process*, in which, as the name implies, the parts to be united are *burned* together, that is, united by fusion of the points by contact of the two plates, etc., under the influence of a hydrogen flame. Preparation is the same as for soldering, save that no "soiling" is necessary. The usual shave-hook and dresser are brought into requisition, but the only appliances necessary are the *blow-pipe flame* and three-cornered sticks of lead prepared similarly to solder.

Fig. 403.

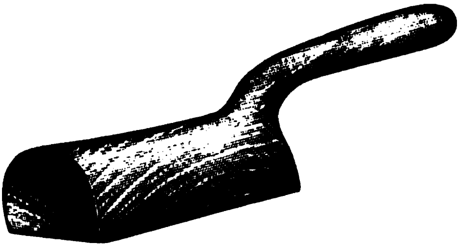

Fig. 404.

WATER PIPE JOINTS.

Cast-iron water pipes are usually made with *spigot* and *faucet* joints, one end of each pipe being chambered out to form a *socket, bell* or *hub*, which receives the other extremity of the next length. The head or spigot end is sometimes turned to fit accurately in the bored-out bell as seen in Fig. 405, but it is usually cast to form with a raised bead around the end, which fits pretty snugly into the socket, thus forming an annulus for the reception of the jointing material.

The pipes being laid in position, the operator caulks twisted oakum or tow into the socket, similarly to packing a gland, working it around and driving it well home until the socket is one-third full of solid yarn. A mould of clay, generally reinforced by rope or yarn, is placed around the pipe, with a good pouring gate and sometimes a vent, and lead is poured in to fill the socket and protrude some ⅛″. The filled socket is as Fig. 406.

The socket *must be filled at one pouring*, and it is also necessary that the annulus be completely filled with lead, for reasons known to every mechanic.

The clay is then removed, and the lead well caulked into the stuffing box of the hub or socket.

A taper *yarning tool*, as the caulking iron is termed, should not be used, as it may drive between the head and the hub, splitting the latter. Care should be taken that the socket is quite dry before pouring, as the molten lead would turn any water into steam, causing an explosion. The workman should stand at the hub end of the pipe when pouring, so that if the joint "blows," the hot metal will fly away from him.

About 1 pound of lead is required for each inch in bore of the pipes, on an average, for each joint.

WATER PIPE JOINTS.

Turned and bored sockets, as Fig. 405, are sometimes caulked with lead, or, at other times, and more especially for heating systems, filled with a rust joint of sal-ammoniac and iron borings.

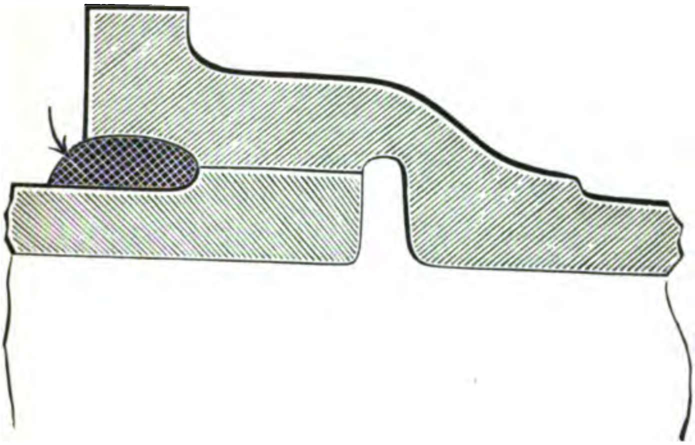

Fig. 405.

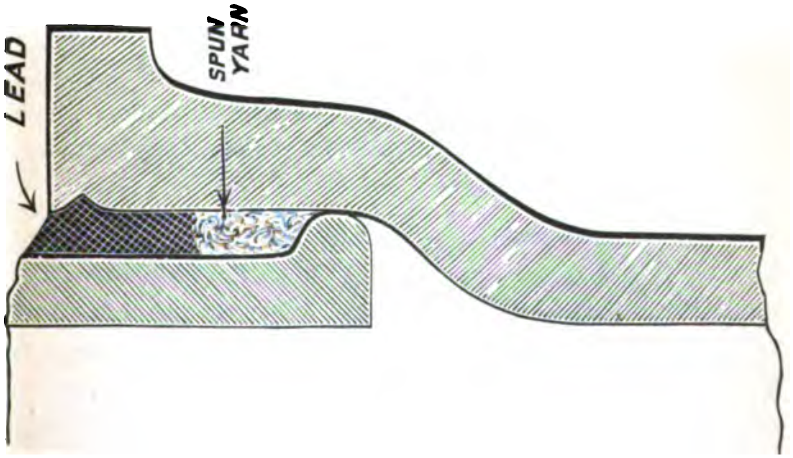

Fig. 406.

METHOD OF PIPE BENDING.

Bending is the act of causing to bend or to curve; *deflection* is a deviation from a common or calculated position. Both are caused by stress, as the bending of a beam under a heavy strain or the deflection of a railway bridge as a train passes over it.

Bending is an important subject for the erector to master intelligently. It should be considered with as much caution as heating steel or iron to the proper temperature, in order to avoid improper manipulation on the anvil, cracks, splits, etc.

To bend a piece of iron or steel there must be some force or pressure applied at the point where the bend is desired. This force or pressure must be greater than the metal's ability to resist it. To forge iron into any desired shape it must undergo a certain degree of bending. If it be required to forge a hand punch of steel of a certain size and length, it would be necessary to reduce one end uniformly to the desired size, by *drawing it out.* During this process each blow of the hammer displaces the molecules to some extent and causes a wave-like motion, which is indicated by the upheaval on all sides of the indentation made by the blow of the hammer.

The second blow makes another indentation and causes another upheaval. This process is continued until the end is reached, the last blow forcing the end smaller. When the metal has been forged to the size wanted, or nearly so, it is necessary to give it a hammer finish. This is done by striking the higher places, driving the low places out even. During the process of bending, the iron or steel is compressed on the inside and stretched on the outside, these two forces meeting in a neutral line near or about the centre. The diminution of that portion above the neutral line is due to prolongation; while the increase of the lower portion is due to compression. Therefore, the decrease of the one side is equal to the increase of the other.

Special implements are made for bending processes, as *bending rolls* for plates and bars; special *pipe-bending machines*, as used with lead or copper pipes; and a *form* or mould around which timbers are bent to the desired curvature.

Bending Lead Pipe.—If any ordinary piece of light lead pipe 1½ inches in diameter is taken and pulled or bent sharply around it will crimple or crinkle at the throat; the larger and thinner the pipe the more it will become distorted.

There are many methods of making bends in lead pipe; for small pipes such as ½ to 1 inch and extra heavy, they may be pulled round without trouble or danger, but for a little larger size *sand bending* is practised, as follows:

Take the length of pipe, say 5 feet, fill and well ram it with sand, 2 feet up, then have ready a metal pot of very hot sand to fill the pipe 1 foot up, next fill the pipe up with more cold sand, ramming it as firmly as possible, stop the end and pull round the pipe, at the same time hammering quickly, working the lead from the throat towards the back, which can be done if properly worked. Care must be used not to reduce or enlarge the size of the bore at the bend.

Bending with Balls.—This method is practised with small pipe and also to take out "dints." Method: Suppose the pipe to be 2 inches, then a ball is required $\frac{1}{16}$ in. less than the pipe, so that it will run through the pipe freely. Now pull the pipe round until it just begins to flatten, put the ball into the pipe and with some short pieces of wood, say 2 in. long by 1¼ in. in diameter, force the ball through the dented part of the pipe. The ball will run through all the easier if "touched" over with a candle end. Care must be used in forcing the ball back and forth not to drive it through the bend.

Before bending, *copper pipes* should be annealed at the spot where it is desired to bend them, the straight portions being left hard. The pipe should be filled with resin or soft lead according to whether the curves are to be of large or small radius. The straight part should not be filled, the progress of the lead or resin being arrested by means of a wad of hard paper thrust in to act as stopper.

The pipes are then bent around stakes or forms, the power being applied by a lever of wood, strapped on the end of the pipe or made fast thereto with rope. Packings of lead and soft wood should be applied at points where pressure is exerted upon the pipes, to avoid bruising. *After the necessary curvature has been attained, the lead or resin is melted out of the pipe.*

BRAZING.

Brazing is the art of uniting metals by means of a *hard solder*. Originally, as its name implies, it was devoted to the union of brass or other copper alloys. Brass filings have been generally replaced by *spelter*, which is a composition of about equal parts of copper and zinc; this is used for brass work. For tubes a composition of 8 parts of brass tube filings to 1 of zinc is used.

Brass or gun metal united by this process will possess a joint as hard as the original casting.

Iron and steel, especially small pieces of finished work, may be united by the same means. The work is first carefully cleaned with acid, and some fine spelter is mixed with borax to form a flux, a little water being added to make a paste. The compound is placed between the parts to be united, as much surface as possible being brought in contact, the two being held in hot tongs, whose heat will melt the spelter and flux by gripping the pieces until firmly united.

Sometimes the work cannot be easily gripped, and so, after inserting the spelter and borax as before, the parts are bound with iron wire and placed in a clear coke fire until the operation is complete. The superfluous metal around the joint will in each case need to be removed by means of the file.

With coppersmiths' work, the joints are prepared either by *thinning* or *cramping*. The first process consists simply of scarfing the edges to a long bevel, and is used for heavy material only. The second, a necessity for lighter work, is rather more elaborate; notches are cut at a slight angle into one of the edges to be united, and the teeth thus formed are bent alternately to left and right. The edge of the other piece is thinned and inserted between the cramp, so that alternate pieces come on opposite sides of the thinned edge, supporting it.

Joints to be brazed are cleaned by covering the parts with a strong brine made from salt and water; they are then heated to a cherry red and plunged into clean fresh water, which also has the effect of annealing the copper. Scouring follows with clean water and sand rubbed on with a wad of tow.

The brazing mixture is made of borax and spelter in equal parts, with water, and is preferably made a day or two previously. The prepared portions of the article to be jointed are placed together and fastened, if for a pipe, by being bound with iron wire. The over-lapping edges are closed by means of a mallet on a stake or mandrel.

The mixture is then laid evenly along the joint, and the pipe or other article placed upon a clear coke fire, the temperature of which is easily regulated. Presently, the borax fuses and forms into *drops*, and then the spelter melts, which is indicated by blue fumes from the zinc. Probably it will be necessary to sprinkle a little more powdered borax, and the pipe may have to be tapped, *chattered* or *jarred*, as it is termed, with a mallet or hammer, to cause the lapped parts to open slightly and permit of the spelter flowing readily in between them. Salt is often strewn on the surface immediately after the spelter has run, to kill the borax, as it would leave a hard scale interfering with future filing.

All flanges to be brazed to copper pipes must be of copper or what is known as brazing metal, 98 copper to 2 of tin, as gun-metal flanges would melt before the spelter ran.

The hole in the flange is slightly tapered, and the end of the pipe also, to form a clearance in which the spelter may flow, a countersink being also formed in the face side of the flange, and

TABLE OF BRAZING SOLDERS.

DESCRIPTION.	COPPER.	ZINC.	TIN.	LEAD.
Coppersmiths' strong spelter..	75	25	...	...
" spelter.......	58	42	...	...
Ordinary refractory spelter..	50	50	...	...
Hard white solder..........	57½	28	14½	...
Half-white, easily fusible....	44	50	4½	1½
Spelter, readily fusible......	33⅓	66⅔	...	...

the pipe slightly opened to fit it. After the mixture is placed in the joint and the parts put together, the countersink is stopped with clay, to retain the spelter. The pipe is then slung vertically over the fire, with the flange underneath, and the previous process carried out.

It will frequently be necessary to close the pipe with a clay tamping or a wooden plug to prevent the heat from going up it. Projections from flanges are protected from the fire by means of a covering of clay.

The blowpipe is almost an essential instrument for obtaining the best results in brazing, etc. It is a tube through which a current of air or gas is drawn through the flame of a Bunsen burner, a lamp or gas jet, or even the flame of a candle. Blowpipes are worked usually by the mouth or bellows.

When gas is used from an apparatus designed for the purpose the *air-cock* is first closed, then the gas-cock is partly opened, and as soon as gas flows from the jet it is ignited.

In brazing cast iron with the blowpipe, brass filings are laid upon the fracture and melted into the joint at a high temperature, making a union which is as strong or stronger than the original texture of the cast iron, it being understood that the surfaces to be joined must be coated with some metallic oxide, usually the oxide of copper made into the consistency of varnish by some suitable liquid and applied on the surface with a brush.

The effect of the metallic oxide is to act as a reducer of the carbon on the surface of the cast iron to be brazed, so that it passes somewhat towards a condition of carbon steel. Without this treatment, a greasy condition of surface may prevent adhesion.

ANNEALING.

Annealing is the process of treating metals by heat to remove their brittleness or hardness and at the same time render them more or less pliable or elastic. These results are generally obtained by heating to a high temperature and more or less gradually cooling. The working of iron or steel by hammering, bending, rolling, etc., tends to harden them and make them brittle, and their original elastic properties are restored by annealing.

Steel dies and the like are annealed in a close box with iron filings or turnings, lime or other substances. They are brought to a red heat and cooled, to exclude air, under sand or other material; the process frees them from carbon and reduces them to pure soft iron, in which state they will readily take, under pressure, the finest engraving from a hardened die. They are subsequently hardened again to the degree necessary for their use. Steel for engraving dies is commonly annealed by heating it to a bright cherry red and cooling very slowly in a bed of powdered charcoal.

Sweating is the process of joining metal objects by filling or surrounding the joint with solder and flux and then heating by means of a lamp, blowpipe or forge until the solder runs and completes the joint. It is akin to brazing, save that a soft solder is used instead of spelter, with consequently a less amount of heat. The term *tinning* is oftentimes applied to the same method or process.

NOTE.—In many cases it is considered an advantage to harden the outside of an article, keeping the inside as soft as possible so as to increase the strength. In such case the article may be heated in *red-hot lead*, the surface of which may be covered with charcoal. Under these conditions the outside of the article, especially if thick will get red hot in advance of the inside.

SOLDER.

Solder is a fusible alloy used for binding together metallic surfaces on being melted upon them. The solder is run along the edges of the joint by means of a heated iron, and partly by chemical attraction and partly by cohesive force it binds the two portions together as it cools and gradually hardens. Many of these alloys are in use, each for different trades or arts, and each has its own melting point, *which must be lower than that of the metals to be united.*

Two classes are used: 1, hard fuse which solders at a red heat and ; 2, the soft solders, which melt at comparatively low temperature.

The soft solders in general use are enumerated in the following

TABLE.

Number.	Parts.		Melting Point Fahr.	Number.	Parts.		Melting Point Fahr.
	Tin.	Lead.			Tin.	Lead.	
1	1	25	558°	7	1½	1	334°
2	1	10	541°	8	2	1	340°
3	1	5	511°	9	3	1	356°
4	1	3	482°	10	4	1	365°
5	1	2	441°	11	5	1	378°
6	1	1	370°	12	6	1	380°

A solder frequently used consists of 2 of tin to 1 of lead, No. 8 in the above list. Cheaper solder is formed by increasing the proportion of lead.

For ordinary plumbers' work, Nos. 4-8 are used, with tallow as a flux ; for lead and tin pipes, the use of No. 8 is general, with a mixture of resin and sweet oil as a flux.

For Britannia metal, pewter, etc., No. 8 is used, with chloride of zinc (killed spirits of salts) as a flux.

TABLE.—WEIGHT OF SHEET LEAD.

Inside Diameter............	⅜	½	⅝	¾	1	1¼	1½	1¾	2
AAA, weight per foot, lbs., oz....	2- 8	3- 0	3- 8	4-12	6- 0	....	...	....	....
AA, " " "	1- 8	2- 0	2-12	3-12	4-12	6- 0	8- 0	8- 8	9- 0
A, " " "	1- 4	1-12	2- 8	3- 0	4- 8	4-12	6- 8	6- 8	7- 0
B, " " "	1- 4	1- 4	2- 0	2- 4	3- 4	3-12	5- 0	5- 0	6- 0
C, " " "	-10	1- 0	1- 8	1-12	2- 8	3- 0	4- 4	4- 0	4-12
D, " " "	- 7	-12	1- 0	1- 4	2- 0	2- 8	3- 8	....	....
E, " " "	....	- 9	-12	1- 0	1-10	2- 0	3- 0	....	....

Sheet lead is not the same weight, bulk for bulk, owing to difference in organic formation, but a cubic foot may be said to weigh 709 lbs.

A square foot 1″ thick, 59 lbs.
“ “ “ $\frac{1}{8}$″ “ 7½ “
“ “ “ $\frac{1}{10}$″ “ 6 “
“ “ “ $\frac{1}{12}$″ “ 5 “
“ “ “ $\frac{1}{15}$″ “ 4 “
“ “ “ $\frac{1}{20}$″ “ 3 “

Sheet lead is sometimes made as thin as writing paper.

PLUMBER'S SOLDER.

Rule for making.—Take 100 lbs. good old lead or lead cuttings, run it down thoroughly, stir it up and take off all dirt or dross: then take 50 lbs. pure tin, let this run down, and when nearly all is melted and is a little cooler throw in ½ lb. of black rosin, and well stir the lot up, Last bring up the heat to 600 degrees which may be known by the burning of a bit of newspaper put in the pot. The solder is now hot enough and should be well stirred and then run into moulds.

For valuable table of weights of sheet lead, etc. see page 378.

BABBITT METAL.

This is a soft white anti-friction metal composed of tin, copper and antimony. Many different compositions of these metals are used for babbitt metal; the alloy originated by Isaac Babbitt was composed of tin 45½ parts, copper 1½ parts, antimony 13 parts, lead 40 parts=100.

At the beginning this proportion was used for all purposes but it has been found that there is no one composition that will bring equally good results in all kinds of machinery, hence are given the following different proportions:

Babbitt metal for light duty is composed of 89.3 parts of copper, 1.8 parts of antimony, 8.9 parts of lead.

Babbitt metal for heavy bearings is composed of 88.9 parts of copper, 3.7 parts of antimony, 7.4 parts of lead.

Lead and antimony have the property of combining with each other in all proportions without impairing the anti-friction properties of either, the antimony hardens the lead, and when mixed in the proportions of 80 parts lead, by weight, with 20 parts antimony, no other known composition of metals possesses greater anti-friction or wearing properties or will stand a higher speed without heat or abrasion.

NOTE.—Formerly, bearings for the journals of machinery were constructed of *brass or gunmetal* (bronze), for the purpose of minimizing friction. Hard cast iron, which afforded an admirable surface becoming glazed over with a sort of skin after a little use, while efficient for sliding surfaces, had to be avoided for journals, as irreparable damage might be done to the bearing when overheated. Later practice evolved the idea of using a softer or elastic metal, popularly known as *anti-friction metal*, which would accommodate itself to inequalities of the surfaces in contact, thus working with far less friction than iron or bronze, while on the other hand it would be much cheaper than a copper-tin alloy.

BABBITT METAL.

Care should be manifested, however, in using it and it should never be heated beyond a temperature that will scorch a dry pine stick.

The practice of lining journal-boxes with a metal that is sufficiently fusible to be melted in a common ladle is not always so much for the purpose of securing anti-friction properties as for the convenience and cheapness of forming a perfect bearing in line with the shaft without the necessity of boring it.

Boxes that are bored, no matter how accurately, require care in fitting and attaching them to the frame or other parts of a machine.

Among all the soft metals in use there are some that possess greater anti-friction properties than pure lead, but lead alone is impracticable, for it is so soft that it cannot be retained in the recess. But when by any process lead can be sufficiently hardened to be retained in the boxes without materially injuring its anti-friction properties, there is no metal that will wear longer in light fast-running journals. With most of the best and most popular anti-friction metals in use and sold under the name of the Babbitt metal, the basis is lead.

NOTE.—It is not good practice, however, to use the shaft for the purpose of casting the bearings, especially if the shaft be steel, for the reason that the hot metal is apt to spring it; the better plan is to use a mandrel of the same size or a trifle larger for this purpose. For slow-running journals, where the load is moderate, almost any metal that may be conveniently melted and will run free will answer the purpose. For wearing properties, with a moderate speed there is probably nothing superior to pure zinc, but when not combined with some other metal it shrinks so much in cooling that it cannot be held firmly in the recess, and soon works loose, and it lacks those anti-friction properties which are necessary in order to stand high speed.

BABBITTING BOXES.

Friction between metals has been the subject of investigation by costly experiments, both by the government and individuals. Even with this expenditure of time and money no absolute conclusions have been reached, hence any rule given for babbitting bearings is subject to practical experience. The following directions have had a wide approval.

Avoid overheating the babbitt, as this is destructive to the qualities of the metal and also entails a considerable loss on account of the dross or scum that has to be skimmed off the ladle. To ascertain the proper temperature, the time-honored test is to try it with a dry pine stick. The temperature should be such that the stick will char without catching fire. Cover the metal with powdered charcoal and put in the ladle a lump of sal-ammoniac.

Of course, it is sometimes necessary to heat the babbitt hotter than this to insure its running to all parts of the box when the section to be filled is thin, but if possible, in such cases, the box should be warmed up to prevent excessive chilling of the metal. If the box is to be babbitted with the shaft in position for a mandrel, be careful to get the shaft properly lined and central in the box. To hold it in position use an outside support if convenient, but if not, small pieces of lead hammered to the right thickness may be used to hold it at the proper height and in a central position. The shaft should be smoked or greased so that the babbitt will not adhere to it and the ends of the box should be stopped with clay or cardboard washers, cut to snugly encircle the shaft and held to the face of the box, to prevent the babbitt escaping. Liners made of cardboard should be inserted between the halves of the box and should touch the shaft on each side so that the box can be divided without trouble after the pouring is completed.

A small hole at one end will be sufficient to insure the lower part filling properly. With a large box and shaft, it is best to pour the lower part first and then the upper one. Care should be taken that there is no water or dampness in the box, as serious consequences may follow if this precaution be neglected.

A rusty box is likely to throw the babbitt, as water will be liberated when the hot metal is poured on it. A small lump of rosin dropped in the ladle just before pouring increases the fluidity of the metal somewhat and reduces the liability of the babbitt to explode when the interior is slightly damp, although no risks should be taken in this direction. If the oil hole is used to pour through, it will be necessary to drill it out and cut the oil grooves after the box is taken apart. If the babbitt is poured from the side, a plug of pine wood can be inserted in the oil hole down to the shaft to keep it clear.

The shaft is sometimes wrapped with a stout cord laid in a spiral direction to get the proper oil runs, but it is usually better to cut them afterwards with a round-nose chisel.

A means of estimation, based on the melting points of metals and metallic alloys, is applied by suspending in the heated medium a piece of metal or alloy of which the melting point is known, (and if necessary, two or more pieces of different melting points,) so as to ascertain, according to the pieces which are melted and those which continue in the solid state, within certain limits the heat of the furnace.

MELTING POINTS OF SOLIDS.

The metals are solid at ordinary temperatures, with the exception of mercury, which is liquid down to—39° F. Hydrogen, it is believed, is a metal in a gaseous form.

All the metals are liquid, at temperatures more or less high, and they probably turn into gas or vapor at very high temperatures. Their melting points range from 39 degrees below zero of Fahrenheit's scale (the melting, or rather the freezing, point of mercury) up to more than 3,000 degrees, beyond the limits of measurement by any known pyrometer. Certain of the metals, as iron and platinum, become pasty and adhesive at temperatures much below their melting points.

MELTING POINTS OF SOLIDS.

VARIOUS SUBSTANCES.	Melting Points.
Sulphurous acid	—148° F.
Carbonic acid	—108
Bromine	+9.5
Turpentine	14
Hyponitric acid	16
Ice	32
Nitro-glycerine	45
Tallow	92
Phosphorus	112
Acetic acid	113
Stearine	109 to 120
Margaric acid	131 to 140
Wax, rough	142
" bleached	154
Iodine	225
Sulphur	239

VARIOUS ALLOYS.

MELTING POINTS OF SOLIDS—(*Continued.*)

METALS.	Melting Points.
Mercury	—39°F.
Potassium	144
Sodium	208
Lithium	356
Tin	442
Bismuth	507
Lead	617
Zinc	680 to 773
Antimony	810 to 1150
Bronze	1692
Silver	1832 to 1873
Copper	1996
Gold, standard	2156
Cast Iron, white	1922 to 2012
" " gray	2012 to 2786
Steel	2372 to 2552
Wrought Iron	2732
Hammered Iron	2912

VARIOUS ALLOYS OF TIN, LEAD, AND BISMUTH.	Melting Points.
3 Lead, 2 Tin, 5 Bismuth	199°
1 " 1 " 4 "	201
5 " 3 " 8 "	212
1 " 4 " 5 "	246
1 " 3	334
2 " 1 "	334
1 " 2 "	360 to 385
3 " 1 "	392
3 " 1 "	552

ALLOYS FOR FUSIBLE PLUGS.	Softens at	Melts at
2 Tin, 2 Lead	365°F.	372°F.
2 " 6 "	372	383
2 " 8 "	395½	406 to 410

THE STEAM BOILER.

A brief description of the parts of the steam boiler and their uses follows:—

Generally the boiler may be considered as a closed vessel in which water is heated for the purpose of generating steam, and confining it under pressure so that its expansive force can be usefully employed. In practice the boiler is partially filled with water to which the heat of combustion is communicated.

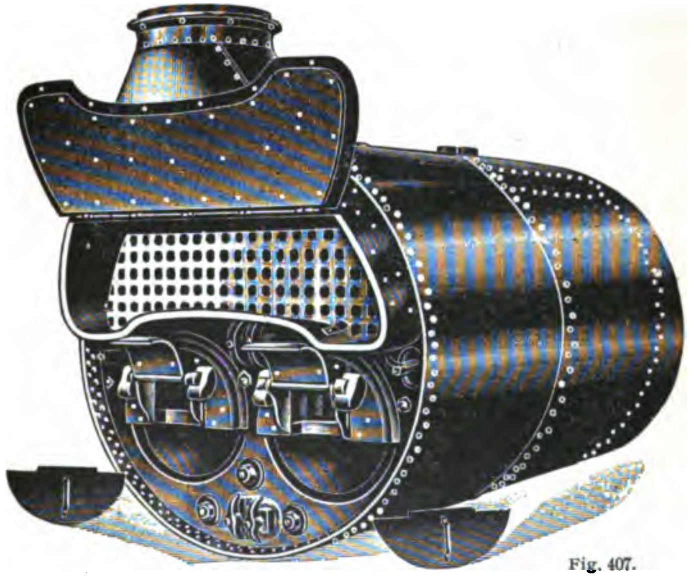

Fig. 407.

The level of the water in the boiler is called *the water line;* the space above the water line is termed *the steam space;* that part of the surface of the boiler exposed to the heat of the fire and the hot gases is called *the heating surface* of the boiler; its measurement is usually given in square feet. The space in which the heat is generated is called *the furnace;* the bars upon which the coal is laid form *the grate surface*, and its dimensions for the purpose of calculations are also stated in square feet.

PARTS OF STEAM BOILER.

Steam boilers may be classified according to their construction and form or according to their application. Thus, we have horizontal and vertical boilers, externally and internally fired boilers, plain cylindrical shell boilers, fire-tube and water-tube boilers. Boilers may be *stationary* or *portable;* there are *locomotive* boilers and *marine* boilers, *semi-portable* boilers, etc. As may readily be seen, each size and type must have its own particular proportions, arrangement and care.

The plain cylindrical boiler consists of a long cylinder called a *shell*, made of iron or steel plates riveted together, the ends of the cylinder being closed by flat plates called *the heads of the boiler.*

The furnace is arranged at the front end of the boiler, the fuel being placed on the grate through the furnace door, the ashes falling through the grate into *the ash pit* below. Behind the furnace is built a brick wall, called *the bridge wall*, which keeps the hot gases in close contact with the under side of the boiler. For long boilers of this class a second bridge wall often is built.

The hot gases flow from the furnace over the bridge walls into *the chimney.* Within the chimney is placed *a damper* regulating the flow of these gases. All portions of the brick work exposed to the action of the gases are made of fire-brick. It is not desirable to allow the upper portion of the boiler to come in contact with the hot gases, and for this reason the boiler above the water line is lined with fire-brick.

Water is forced into the boiler through *the feed pipe* leading into the lower end of the boiler by the aid of *an injector* or a pump. To prevent the steam from rising above a certain pressure, *a safety valve* is placed at the top of the boiler.

BOILER ATTACHMENTS.

From the highest part of the boiler, also, *the main steam pipe* leads the steam to the engine or any apparatus by which the steam is to be utilized.

The pressure of the steam in the boilers is indicated by *the steam gauge* (Figs. 421 and 422) attached to a pipe which passes through *the front head* into *the steam space of the boiler.* To determine the water level, *try cocks* are placed in the front head of the boiler shell. There are, commonly, three of them in one vertical line; the level of the water may be found approximately by opening these try or test cocks.

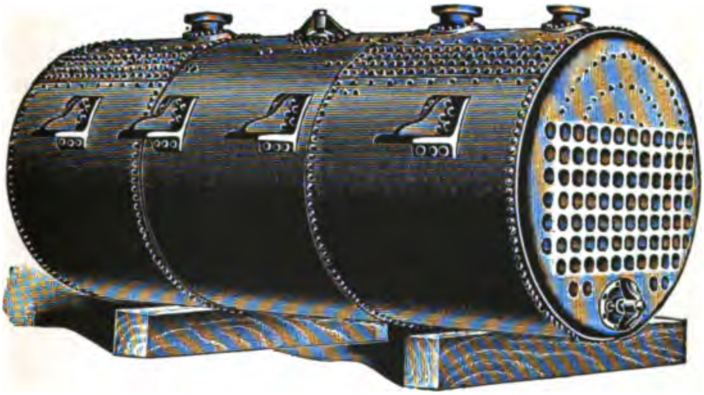

Fig. 408.

The level of the water may also be shown by a *water column*, illustrated in Fig. 420. Valves at the top and bottom allow the steam to be shut off if the glass breaks or needs cleaning, and a *pet cock* at the bottom allows the water to be blown out of it. The brass fittings of the water glass are often screwed directly into the boiler plates; when this cannot be done, the water glass may be put on the water column.

CYLINDRICAL AND FLUE BOILERS.

The boiler must also be provided with a *blow-off pipe*, through which the water may be discharged; in Fig. 411 *the feed pipe* as well as the blow-off may be seen at the ends of the boiler.

A *manhole*, Fig. 417, is constructed in the front head or on top of the boiler, to allow a person to enter for the purpose of cleaning, inspecting or repairing. At the lower side of the boiler a *hand-hole* is generally sufficient, as in Fig. 418, for cleaning it out and removing the accumulated sediment.

Plain cylindrical or plain shell boilers may be made from 30 to 40 inches in diameter and from 20 to 40 feet long; they are not considered economical on account of their small heating surface.

The *flue boiler* differs from the plain shell boiler in having one or more large flues running lengthwise through the shell, below the water level. The hot gases pass from the furnace over the bridge walls and then through the flues to the *smoke-box* and chimney. This type of boiler is more economical than the plain shell boiler, as the flues considerably increase the heating surface. It is used wherever the water is bad, even though it may not be as economical as some other types of boilers.

The *horizontal tubular boiler*, Fig. 408, is a development of the flue type. It consists of a cylindrical shell, closed at the ends by two flat tube plates and of numerous fire-tubes, usually having a diameter of three or four inches. About two-thirds of the boiler is filled with water; the other third being the steam space. The water level must be six or eight inches above the highest row of fire-tubes.

Vertical tubular boilers consist of a cylindrical shell placed in an upright position; it requires little room; the fire-box occupying the lower end of the cylinder whence the products of combustion pass upward through a round nest of tubes.

SCOTCH BOILER.

The *fire-tubes* hold the two ends of the boiler rigidly together, acting as stays, but as these are placed only below the water line, the upper parts of the flat plates are braced by *through rods* or stays, or *diagonal stays*.

The boiler is supported by the side walls by means of brackets riveted to the shell.

The Scotch boiler, otherwise called the *marine boiler*, is shown in Fig. 407; it has also been descriptively named the *multi-return tubular boiler*. The fact that it is self-contained, and that not only its fire-box but its ash pit is internal, has rendered it especially suitable for marine work, for the danger from fire—so dreaded—is reduced to a minimum.

What is particularly interesting in this type of boiler is its growth. The small sizes required by the earlier engines, and to which they were limited by the sizes and thicknesses of sheets that were obtainable, have given place to the mammoth affairs of our modern liners and battleships. The tubes which were originally expanded and possibly beaded over on the smoke box end are now screwed into the sheets, where they are further used as stay tubes.

It is interesting to note, however, that while the diameter of the boiler has risen twofold or more, the length and diameter of the tubes, with the thickness of the metal composing them, has changed but little.

NOTE.—One of the greatest improvements in the Scotch boiler has been the introduction of the corrugated flue. It is a matter of detail that has probably been productive of more actual money saving in the way of repairs and the prevention of disasters in the marine service, *to say nothing of nervous wear and tear on the part of the engine-room force*, than any other improvement that has been made on any type of boiler.

WATER TUBE BOILER.

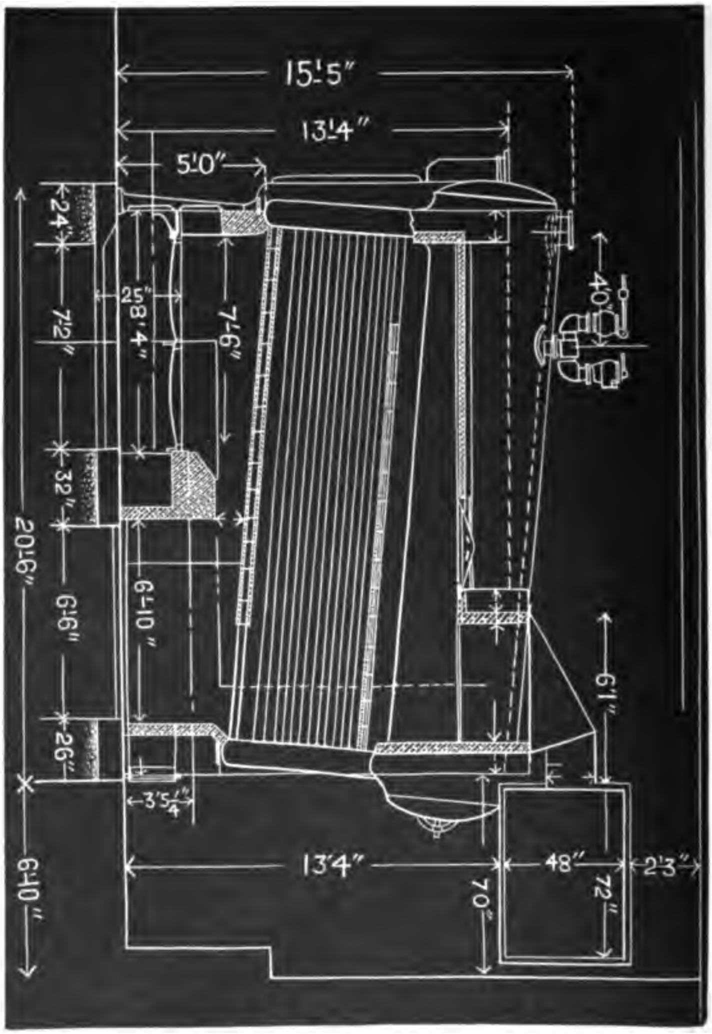

Fig. 409. See page 409.

MARINE BOILER.

This type of marine boiler may be *single or double ended.* In the latter case it has combustion chambers common to either end, or else separate. As a usual thing, Scotch boilers are large in diameter to accommodate furnaces and return tubes all in one end ; for special uses, as where head-room is limited, a modified form is built.

The Scotch boiler is essentially a boiler for high pressure and has, for this reason, most of the important members in cylindrical shape. They are all arranged horizontally. The gases pass to the back and are returned to the front for discharge.

The important parts of this boiler are :—

(1.) The cylindrical shell, which encloses the steam and water-space.

(2.) From one to four cylindrical furnaces that provide room for the grate. The grate divides the furnaces into the space for the gases above, and the ash-pit below the grate.

(3.) Cylindrical tubes in large number, above and parallel to the furnaces. These constitute the bulk of the heating surface and lead the gases to the uptake at the front of the boiler.

(4.) From one to three combustion chambers, for the combustion of the gases. These form the passages for the gases from the rear end of the furnaces to the tubes; they have flat tops, backs and tube plates, and sides that require staying to resist the pressure of the steam.

(5.) Heads to close the ends of the cylindrical shell. These require staying to resist the steam pressure, and this is provided, partly by special bolts, partly by the tubes.

(6.) Uptake and funnel to carry off the burnt gases.

WATER TUBE BOILER.

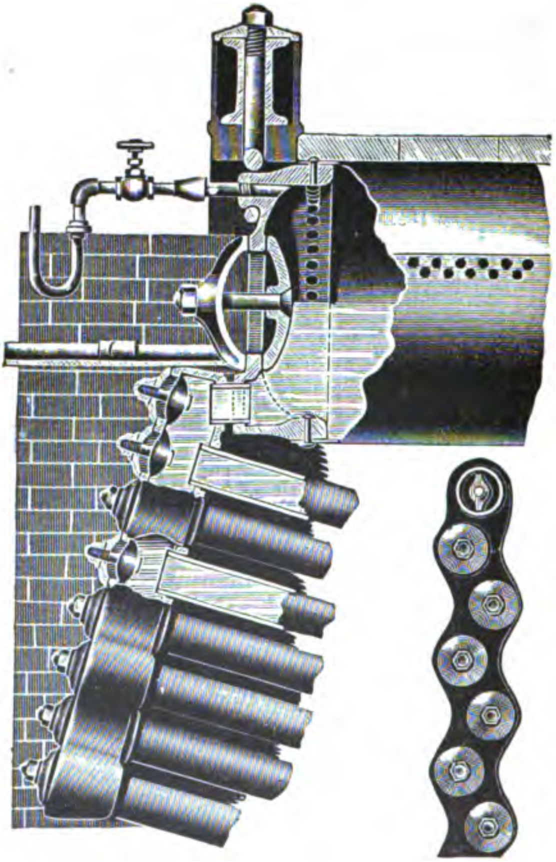

Fig. 410. See page 409.

NOTE.—Engine and boiler rooms can be made bright and pleasant by making the surfaces white. Lime is a good non-conductor of heat, and it has the further quality of protecting iron from rust. To prepare whitewash for this purpose it is only necessary to add a little salt or glue to the water used for dissolving the lime, as either of these substances will make it stick readily, and it cannot afterward be easily rubbed off.

HORIZONTAL TUBULAR BOILER.

The horizontal tubular boiler is shown in Fig. 408. It is a very widely used type for the following reasons:—

(1.) The cylindrical form is the strongest.
(2.) It is manufactured easiest.
(3.) It encloses the greatest volume with the least material.
(4.) It permits the use of thinner metal.
(5.) It resists internal as well as external strain.
(6.) It is inspected without difficulty.
(7.) It is most symmetrical.
(8.) It is the cheapest.

In this type of boiler the shell is filled with as many small tubes, varying from two inches to four inches in diameter, as is consistent with the circulation and steam space. In firing the combustion first takes place *under the shell*, and the products, such as heat, flame, and gas, *pass through the small tubes to the chimney*.

Some further description of this steam boiler will be found on page 386; a *side view* of its setting is shown in Fig. 411; a *plan or top view* is seen in Fig. 414; Fig. 415 is a *vertical sectional view* showing still further details; Fig. 416 exhibits a view of the same resting on timbers or blocking ready to be bricked up.

A somewhat extended description of the setting of this boiler is given in succeeding pages.

The two principal types of boilers heretofore described belong to what are known as *fire-tube boilers*; a widely used and also popular form of boiler is illustrated in the side sectional view, Fig 409; this is known as *a water-tube boiler.*

The distinguishing difference, which marks the water-tube boiler from others, consists in the fact that in the former the small tubes are filled with water instead of the products of

HORIZONTAL TUBULAR BOILER.

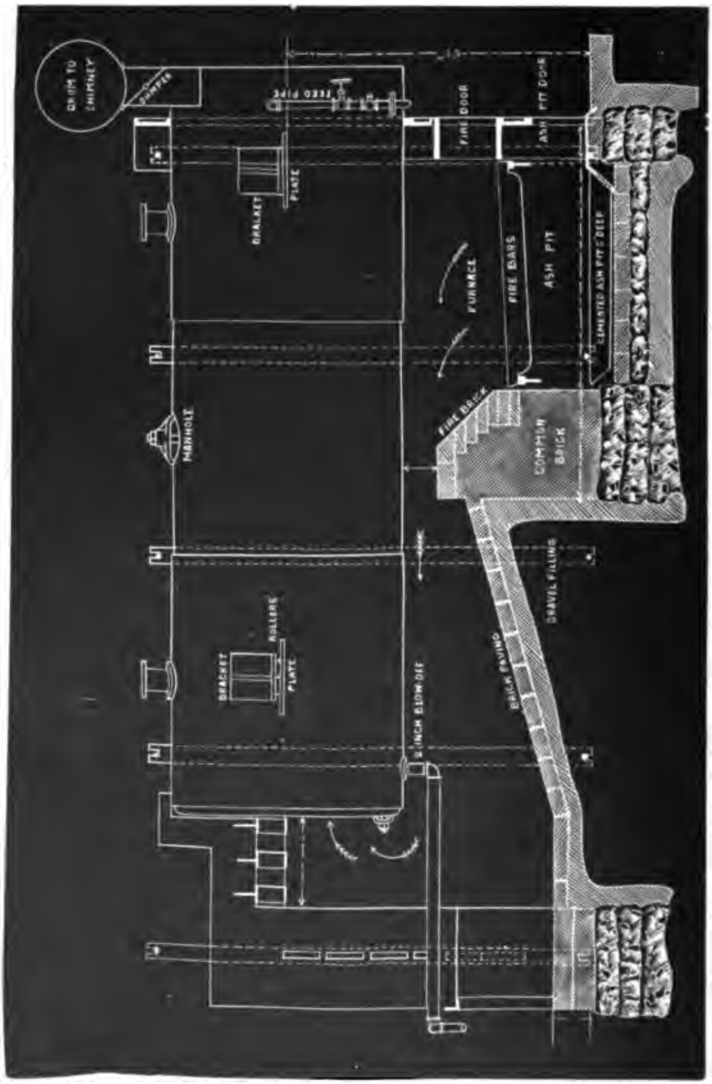

Fig. 411.

combustion; hence the comparison, frequently made, between water-tube and *fire-tube* boilers—the difference has been expressed in another way, "Water-tube vs. shell boilers," but the principle of steam production in both systems remains the same; the heat from the combustion is transferred to the water through the medium of iron plates, and in both, the furnaces, steam appliances, application of the draught, etc., is substantially the same. In another important point do the systems agree, *i. e.*, in the average number of pounds of water evaporated per lb. of fuel.

The advantages claimed for this form of steam generator are as follows:

(1.) Safety from disastrous explosions, obtained by the division of the contents into small portions, and especially by details of construction which make it tolerably certain that the rupture will be local instead of a general violent explosion which liberates at once large masses of steam and water. (2.) The small diameter of the tubes of which they are composed renders them much stronger than ordinary boilers.

(3.) They can be cheaply built and easily repaired, as duplicate pieces can be kept on hand. The various parts of a boiler can be transported without great expense, trouble or delay; the form and proportions of a boiler can be suited to any available space; and, again, the power can be increased by simply adding more rows of tubes and increasing the grate area. (4.) Their evaporative efficiency can be made equal to that of other boilers. (5.) Thin heating surface in the furnace, avoiding the thick plates necessarily used in ordinary boilers, which not only hinder the transmission of heat to the water, but admit of overheating.

(6.) Joints removed from the fire. The use of lap welded water tubes with their joints removed from the fire also avoids the

WATER-TUBE BOILERS.

unequnal expansion of riveted joints consequent upon their double thickness. (7.) Quick steaming. (8.) Accessibility for cleaning. (9.) Ease of handling and erecting. (10.) Economy and speediness of repairs.

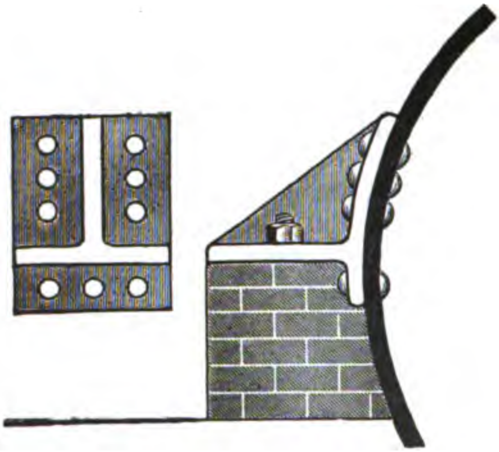

Fig. 412.

Fig. 410 illustrates the details of construction of a well-known form of the wat[illegible]ube boiler.

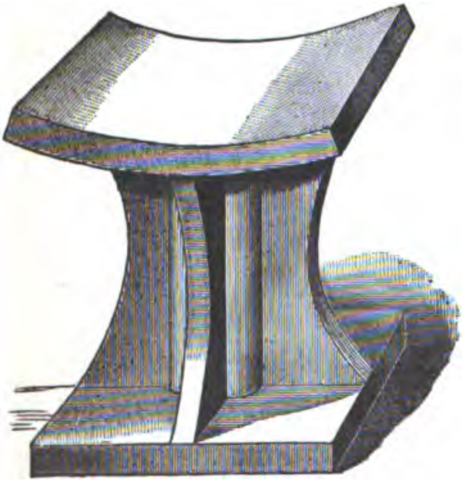

Fig. 413.

The small water capacity of tubular boilers, while it facilitates steam rising, does not provide storage for much heat energy, and the pressure is apt to fluctuate widely. This is mitigated by carrying 50 lbs. more steam in the boilers, and interposing *a reducing valve between them and the engine.* Automatic feed arrangements are also necessary.

BOILER SETTINGS.

The method, either bad or good, in which steam boilers are "set" or arranged in their brick work and connections will vary the quantity of fuel used by as much as one-fifth ; hence the importance of knowing the correct principles upon which the work should be done.

The portion of the steam plant called "the boiler" is composed of two parts—the boiler and *the furnace*, and the latter may be considered a part of the "setting," as it is mainly composed of brick work.

Two kinds of brick are used in boiler setting—the *common* brick for walls, foundations and backing to the furnace, and so-called *fire brick*. The quality in fire brick which renders them useful is their power to resist for a long time the highest temperatures and sudden changes of temperature without injury, and their ability to resist the action of melted copper or iron slag. Fire brick are cemented together with fire clay, which is quite unlike the ordinary mortar which is most suitable for common brick.

Fire brick should be used in all parts of the setting which are exposed to the hot gases. It is better to have fire brick lining tied in with red brick work, unless the lining is made 13½ inches thick, when it can be built up separate from outside walls. This arrangement will require very heavy walls. As usual, but 9 inches fire brick lining is used in the fireplace and 4½ inches behind the bridge wall. Joints in the fire brick work should be as thin as possible.

The setting as well as construction of boilers differs greatly, but in all the end to be sought for is *a high furnace heat*, with as little *waste as possible, at the chimney end.* To attain this there must be (1) a sufficient thickness of wall around the furnace,

FURNACE PARTS.

including the bridge, to retain as nearly as may be every unit of heat. (2) A due mixture of air admitted at the proper time and temperature to the furnace. (3) A proportionate area between the boiler and the surface of the grates for the proper mixing of the gases arising from combustion. (4) A correct proportion between the grate surface, the total area of the tubes, and the height and area of the chimney.

The principal parts and appendages of a furnace are as follows:

The furnace proper or fire box, being the chamber in which the solid constituents of the fuel and the whole or part of its gaseous constituents are consumed.

The grate, which is composed of alternate bars and spaces, to support the fuel and admit the air.

The dead-plate, that part of the bottom of the furnace which consists of an iron plate simply.

The mouthpiece, through which the fuel is introduced and often some air. The lower side of the mouthpiece is the dead-plate.

The fire door. Sometimes the duty of the fire door is performed by a heap of fuel closing up the mouth of the furnace.

The furnace front is above and on either side of the fire door.

The ash pit. As a general rule the ash pit is level, or nearly so, with the floor on which the fireman stands, and as for convenient firing, the grate should not be higher than 28 to 30 inches, the depth of ash pit is thereby determined.

The ash pit door is used to regulate the admission of air.

The bridge wall.

The combustion or flame chamber.

SETTING OF TUBULAR BOILER.

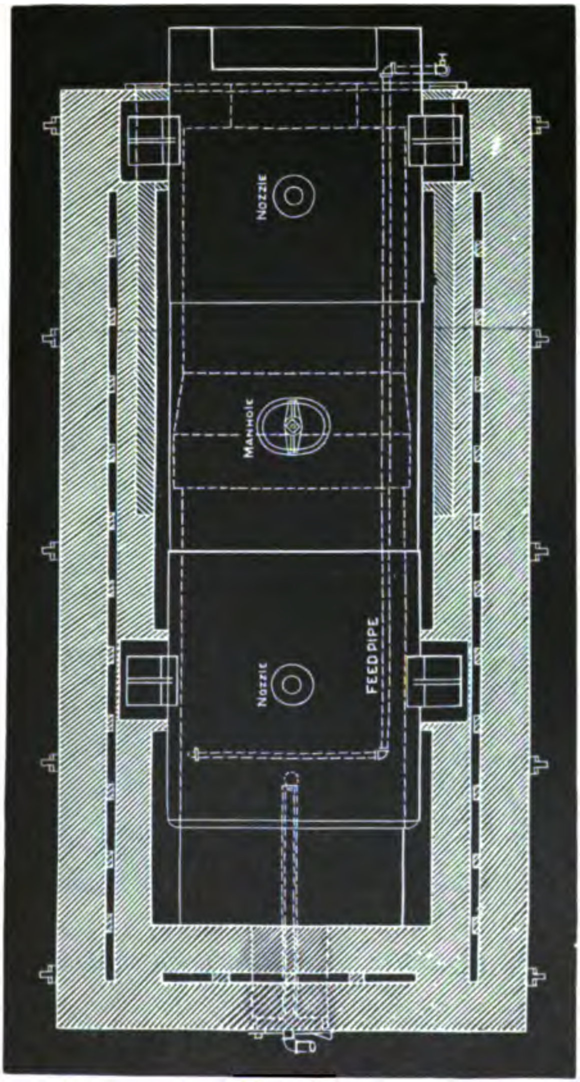

Fig. 414.

BOILER SETTING.

In setting boilers it is a matter of primary importance *that good drainage be assured*, as corrosion of the shell plates leading to serious damage may be caused by dampness arising from the foundation. This may be occasioned either from erecting the boilers on wet ground or in such a site that surface water may accumulate.

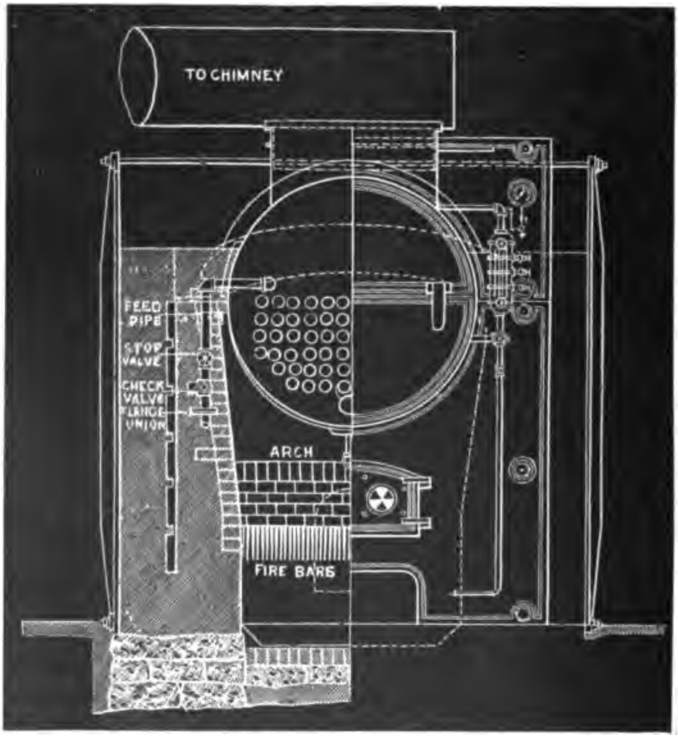

Fig. 415.

The depth to which the foundations should go depends upon the nature of the soil. Trenches may be dug to a depth of three or four feet, and footings placed within them, according to the

BLOCKING UP BOILER.

methods explained in preceding sections of this book. *Large stones or concrete* are to be recommended for the footings of the walls and bridges, the earth being well rammed into the trench as soon as the walls have risen above the ground level.

If the ground is soft, the whole area should be excavated to three feet depth, and the pit filled with two feet of sand or gravel well rammed, or still better, with concrete. On marshy ground, wooden platforms or grillage may have to be used, in connection with short driven piles, all woodwork being entirely submerged to prevent its decay. *Heavier foundations should be used for boilers than for ordinary buildings*, as the least settlement may be dangerous, setting up strains caused by weight.

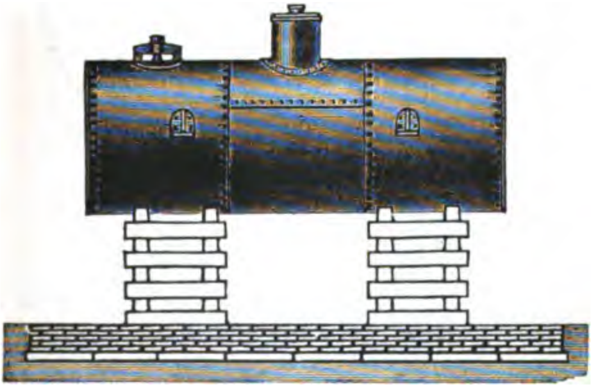

Fig. 416.

NOTE.—As all brick *shrink more or less in burning*, it is well—in furnace setting—to assort even pressed brick into piles of different thicknesses in order to get first-class work. *The weight of bricks* varies considerably with quality of the clay from which they are made and of course with their size. Common brick average about 4½ lbs. each. In the U. S. there is no legal standard for *the size of brick*; they vary from 7¾x3¾x2¼ to 8¼x4¼x2¼ inches.

BOILER FITTINGS.

The setting proper is shown in *sectional elevation* in Fig. 411, in *plan* in Fig. 414, and in *vertical cross section* in Fig. 415, as mentioned above.

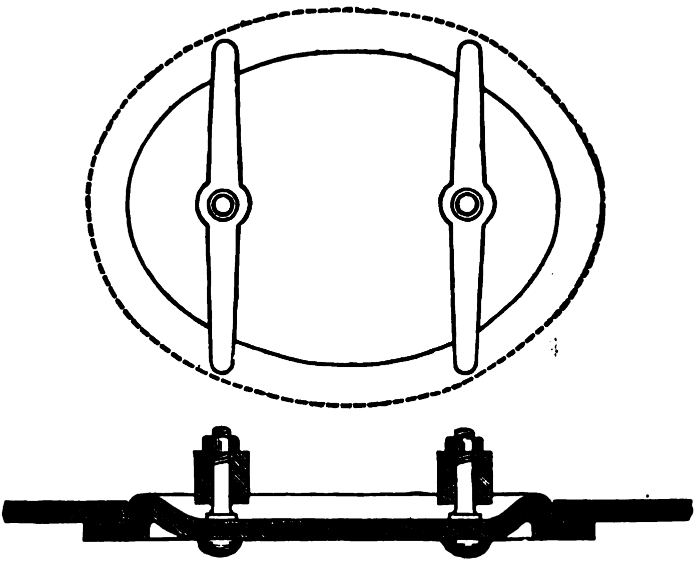

Fig. 417.

This setting is known as the *projecting* front and costs less for repairs and no more to put in than the *flush* front, while it is also of better appearance. *The walls*, from a distance not less than four inches below the boiler-room floor or the ash-pit, as the case may be, should be of hard burned brick; for above this they will be exposed to a greater degree of heat, and bricks will stand the heat better than any other building material. Those bricks used in the inner face should be selected from the lot.

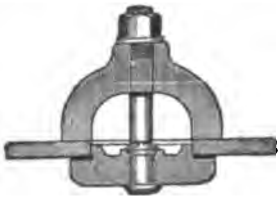

Fig. 418.

FIRE BRICK AND CLAY.

The mortar used should be composed of one part of lime with four to six parts of clean sand, well screened, and the joints should be as thin as they can be laid, not over one-eighth of an inch thick, especially those exposed to the heat of the furnace.

Mortar in Boiler Setting.—To build any kind of brick structure so as to make a strong and durable piece of work, it is necessary to have a bed of some kind of mortar between the bricks. Brick work therefore consists both of mortar and bricks. The function of the mortar in brick work is *threefold;* 1, to keep out wet and changes in temperature by filling all crevices; 2, to unite the whole in one mass; 3, to form a cushion to take up any inequalities in the bricks and to distribute the pressure evenly.

The furnace itself should be lined with fire brick, which should be laid in contact with each other; a thin paste of fire clay, enough to fill up the irregularities of their surfaces and give them a solid bearing, being all the mortar that is admissible. In laying fire brick, each one should be dipped into water as it is used, so that it will not immediately drink up the water from the mortar. They should then receive a thin coating of the kaolin or fire clay, and be placed in position. The fire clay should be mixed up so thin that it cannot well be laid on with a trowel, an iron spoon being preferable.

The four principal designs of boiler fronts are, (1) the *flush front*, (2) the *overhanging front*, (3) the *cutaway front*, (4) *fronts with breeching*. The flush front is liable to certain accidents.

NOTE.—One of the commonest defects which are apparent in boilers set with a flush front is the burning and breaking off of the shell on the lower side just forward of the front tube sheet. This is caused by the fire brick arch over the furnace door becoming loose and falling down, thus exposing the dry portion of the shell to the direct action of the intense heat of the furnace fire.

BOILER SETTING.

Every sixth course, beginning with the grates, should be a row of *headers*, well bonded into the masonry behind; the headers being of little use unless they are so bonded, for when the lower courses of fire brick have been burned away, it is necessary to rely on the headers to a great extent to hold the upper part of the wall in position, and if they have been laid with due care the lower courses can be removed and replaced without disturbing the upper part of the wall. If the headers are not secured the entire wall will have to be rebuilt.

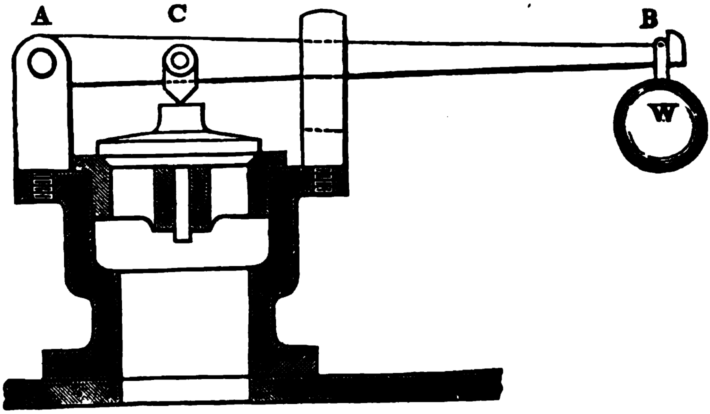

Fig. 419.

The side and rear-end walls should always be double, with a two-inch air space, as shown in the cuts. The object of the air space is to prevent the leakage of heat as much as possible. The walls should not be bonded together, but there should be projecting bricks from the outer wall, extending in and touching the inner wall. This leaves the inner wall free to expand under the influence of heat, without affecting the outer one, and still leaves the latter in the position of a retaining wall. Both of the rear walls are of the same thickness, 12 inches, in every case, as is the outer side wall. The inner side wall is 16 inches thick at the bottom, and tapers up to 9 or 10 inches at the centre line of the boiler.

The batter is entirely on the inside, as shown in Fig. 415, and begins just above the grade. This mode of construction leaves an air space of 3 or 4 inches at the centre line of the boiler, gives ample room at the sides for the circulation of heated gases, and affords an opportunity for making an inspection of the shell and for making repairs. It also gives greater stability to the wall and the removal of soot and ashes is greatly facilitated, as these do not adhere so readily to the sloping wall.

The office of *the bridge wall* is to form a back to the furnace and it should be flat on top; that is, not curved to conform to the shape of the boiler. Beginning about 4 inches above the grate, it slopes back at an angle of 45°, in order that the radiant heat from the fire may be diffused over as large a surface as possible.

In addition, this construction hinders the formation of clinkers and the deposition of ashes on top of the bridge wall and makes it easier to keep the fires clean at this point. The top of the bridge wall should be 9 or 10 inches from the bottom of the boiler according to the size of the boiler.

The grates are set 24 inches above the floor level in every case; and pitch backward 3 inches to the bridge wall. This gives a thicker layer of coal at the rear end of the grate and thus promotes uniformity of combustion ; because with a uniform layer of coal, the air will naturally pass through more freely at the rear.

In addition, *the pitch makes slicing and firing easier.* The top of the front end of the grate is from 24 to 28 inches below the boiler shell, varying with the size of the boiler. The width of the grate should be six inches less than the diameter of the

WATER COLUMN.

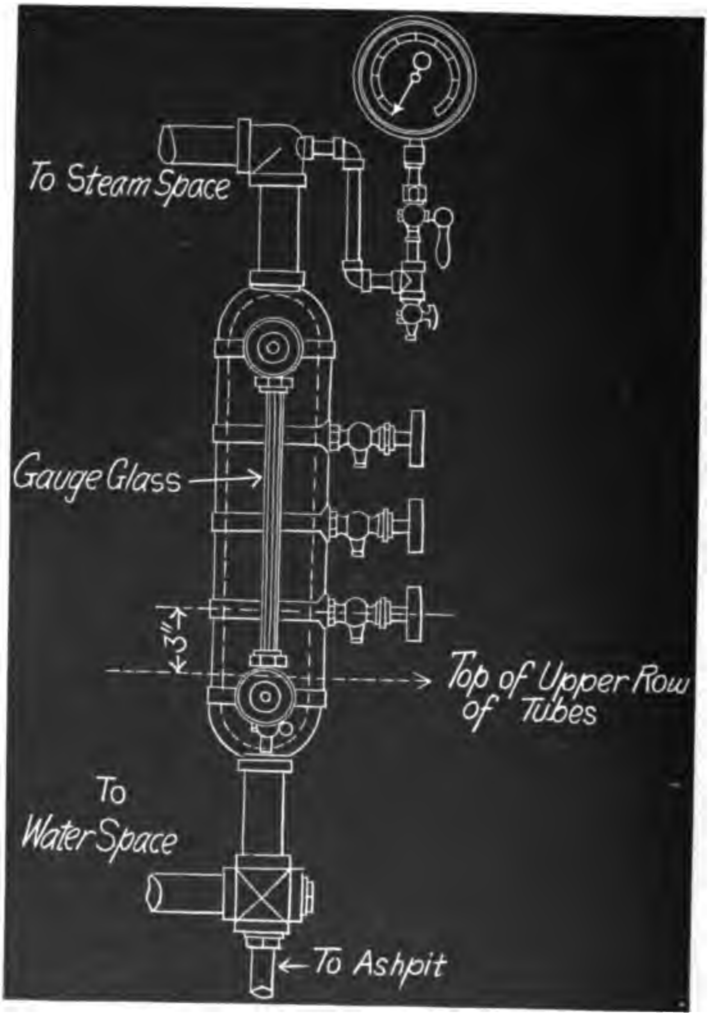

Fig. 420.

boiler. The length of the grate recommended by the Hartford Steam Boiler Insurance Co. is equal to the diameter of the boiler; but this may be varied, depending on the kind of fuel used, the rate of combustion, and the amount of heating surface in the boiler.

Back of the bridge wall an incline is made by filling in with earth paved over with bricks. The rear wall has an opening 24 inches high and 16 wide; and this, together with the incline, makes it an easy matter to hoe out the ashes from the back connection at almost any time, without waiting to stop the boiler and let the setting cool, and in addition, as the cleaning door is placed on a level with the flame bed, it is below the currents of highly heated gases, and loss by radiation through the door is largely prevented. The floor of the flame bed should be 8 inches above the floor level.

The ash pit is best made about 6 inches deep, with the sides sloping at an angle of 45 degrees, with a good layer of cement over the bottom and up the sides to keep it water tight. When running, the ash pit should be kept full of water, as this serves to keep the grates from warping; the pit is kept cool by the quenching of the coal and hot ashes that drop through ; and, in addition, the vapor always rising aids combustion by keeping the fire cleaner on the under side.

The back connection is covered in by a brick arch resting on cast-iron bars, as shown in cross section in Fig. 411. Their ends rest on the side walls of the setting, and the rise of the arch should be sufficient to render the tubes easily accessible at the back end. The arch is better if made of fire bricks, but, for ordinary use, when the boiler and grate surface are well proportioned and the boilers are not forced, ordinary hard burned bricks will answer. The closing in at the back end is best done by carrying the brick work up above the top of the arch even with the upper part of the shell, curving it to conform with the curve of the shell, and plastering over.

Much of the preceding remarks on setting boilers applies to the arrangement of the brick work with water-tube boilers, but, there are, however, two noteworthy points of difference. *The water-tube boiler is almost invariably suspended apart from the brick work*, the drums and tubes being usually slung from girders supported on columns, or else suspended by transverse angle or channel bars connected with a steel framework. This renders the boiler quite free from the brick work, to expand or contract, without throwing any strain upon the latter. The brick work, therefore, has only to guide the movement of the heated gases and to enclose the furnace.

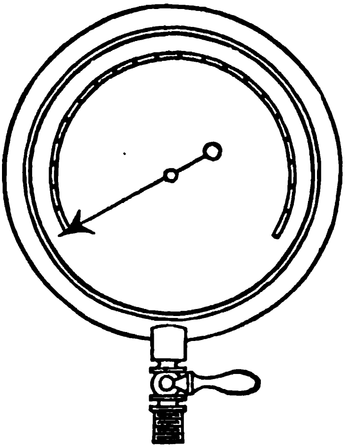

Fig. 421,

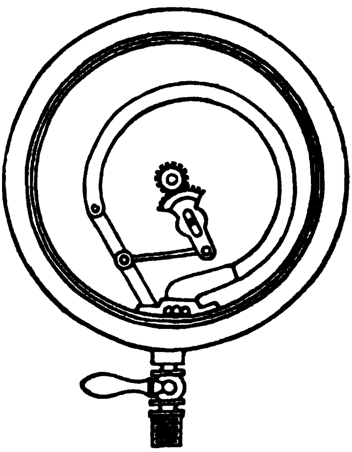

Fig. 422.

The baffle work consists of very light tiling and thin bricks, quite likely to give way ; thus heavy losses may be sustained from

SETTING WATER-TUBE BOILERS.

defects or omissions in the brick work and leakage of the cold air through the external walls. Although this form of boiler is not liable to destructive explosion, the same care should be exercised to avoid possible damage to the boilers and expensive delays.

The soot and ashes collect on *the exterior* of the tubes in the water-tube boiler, instead of inside the tubes, as in the tubular, and they must be periodically removed. This can be done by the use of blowing pipe and hose through openings left in the brick work; in using bituminous coal the soot should be brushed off when steam is down. All the inside and outside surfaces should be kept clean to avoid waste of fuel; to aid in this service the best forms are provided with extra facilities for cleaning. For inspection, remove the hand-holes at both ends of the tubes, and by holding a lamp at one end and looking in at the other the condition of the surface can be freely seen.

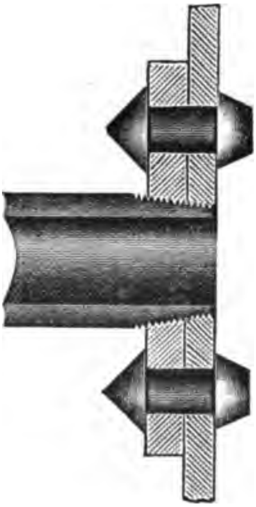

Fig. 423.

The illustrations given in Figs. 409 and 410, pages 390 and 392, represent two popular types of water-tube boilers, in which, apart from the special design of the headers or water-legs, all tubular parts are made of ordinary mercantile steam tubing, and replacement of damaged portions is easy.

NOTE.—Water-tube or sectional boilers have been made since the days of James Watt, in 1766, in many different forms and under various names. Owing, however, to the imperfection of manufacture, the system, as compared to shell boilers, was for a long time a failure, but various patterns of water-tube boilers are now in most satisfactory use.

SETTING WATER-TUBE BOILERS.

This will be necessary sooner or later, as the thin baffle plates over the furnace, in Fig. 409, will warp and require renewal, and some of the tubes may have to be removed to effect this. The advantage of being able to replace them immediately by lengths cut from standard pipe will be apparent.

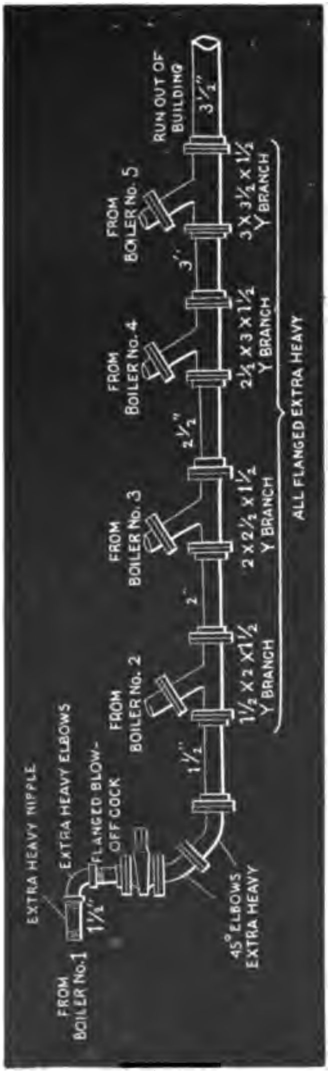

Fig. 425.

It is customary with this class ~~of boiler~~, ~~when~~ of small size, to ship them fully built up, with the exception of the drum, which will have to be put in place after the boiler has been erected upon its foundations, and the connecting tubes leading to the headers will have to be expanded into the shell.

Doors to close the various openings in the brick work may be made of cast iron and lined with two-inch blocks of magnesia or asbestos, which are supplied shaped for the purpose and provided with bolt holes for affixing them to the frame.

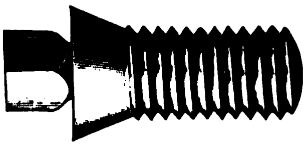

Fig. 424.

NOTE.—For explanation of these two figures see page 416.

BOILER ATTACHMENTS.

The proper operation of the boiler as to efficiency and economy is largely dependent upon the appropriate proportion and harmony of action of its numerous fittings; the utmost care and skill based upon practical experience are requisite both for designing and attaching them.

A boiler is not complete without fixtures; there must be a feed-pump or injector, with a supply pipe, feed-valve, safety feed-valve, and check-valve, in order to supply water properly to the boiler; gauge-cocks, a glass water-gauge, a blow-pipe, with its valve, to reduce the height of the water in the boiler, or to empty it entirely; a safety-valve to allow the steam to escape from the boiler when it exceeds a fixed pressure; a scumming apparatus to remove the foreign matters from the water as much as possible; a steam-pipe to convey the steam to the place where it is wanted; manholes and hand-holes, with their covers and guards, for examination and cleaning; a non-corrosive steam-gauge, to accurately indicate at all times the amount of pressure in the boiler; and a fusible plug to give warning in case of "low water."

The fittings of the marine boiler are similar to those belonging to the land steam generators, and vary only in accommodating themselves to their peculiar surroundings.

NOTE.—All these belong to the boiler proper, having direct reference to its internal functions; but in addition there are the lugs, pedestals, or brackets which support the boiler; the masonry in which it is set, with its binders, rods, and wall-plates; the boiler front, with its doors, anchor-bolts, etc.; the arch plates, bearer-bars, grate-bars, and dampers, and last, but not least, the chimney. These are all equally necessary to enable the boiler to perform its duty properly. And besides, there are required fire-tools, flue brushes and scrapers, and scaling tools, with hose also, to wash out the boiler, to say nothing of hammers, chisels, wrenches, etc.

MAN AND HAND HOLE COVERS.

Thus we see that in speaking of a boiler, not only the boiler proper is meant, but also the whole of its fixtures and belongings, of which the following is only a partial list; it must not be supposed that a complete list and description of all steam-boiler attachments are here presented; *however, it is well for the author to add*, and well for the erector—either millwright or machinist—to become thoroughly familiar with these fixtures—both name and use—as also with the boiler itself.

Figs. 412 and 413, page 396, show approved boiler bearings; the upper illustration is that of a boiler *lug;* four of these are designed to be riveted on each side of an average boiler (72 inches diameter, 18 feet long), with 6 one-inch rivets in each one. Fig. 413 represents a chair or pedestal frequently used for the support of small boilers. In medium or larger sized boilers *both supports are often used as a measure of safety.*

The manhole cover shown in Fig. 417 is a plate and frame commonly opening inwards and large enough to admit a man into the interior of the boiler. Manhole openings in steam boilers should invariably be located in the head of the boiler, except in rare cases that may arise, when circumstances require it to be placed in the shell. The manhole, so placed, will not materially reduce the strength of the boiler, and from this position it can more readily be seen that the boiler is kept in proper condition. The proper sizes for manholes are 15x10 or 16x11 inches according to circumstances.

A hand-hole plate, Fig. 418, is an arrangement similar to the manhole cover except as to size. They are made large enough to admit the hand into the boilers for the purpose of removing sediment and are also used for the purpose of inspecting the interior of the boiler. Two are usually put in each boiler, one in front and one in the rear.

The *safety-valve* is a circular valve, shown in Fig. 419, seated on the outside of the boiler and weighted to such an extent that when the pressure of the steam exceeds a certain point the valve is lifted and allows the steam to escape.

The effective pressure on the lever safety-valve can be regulated within certain limits by sliding the weight along the arm and in the spring safety-valve the pressure can be regulated by altering the tension of the spring.

Every boiler should be provided with two safety-valves. The size of the opening into the boiler depends upon its steam-producing qualities, the object to be attained being to reduce the pressure within the boiler to its safety point as quickly as possible.

Safety-valve calculations is a subject, while old, is ever new to the engineer, and rules have been made up in such a manner that any one who can add, subtract, divide and multiply and *read decimals* can soon acquire familiarity with the rules, and thus make them his own when he needs to use them in adjusting a safety-valve.

A combination water column is shown in Fig. 420. The water line in the boiler is indicated by a water glass and gauge-cocks. These may be connected directly with the front head or with the column, which in turn is connected with the boiler at top

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NOTE.—It may be stated, as applying to all valves, that the *seat of the valve* is the fixed surface on which it rests or against which it presses, and *the face of a valve* is that part of the surface which comes in contact with the seat. The *spindle* is the small rod which projects upward or downward from the middle of the valve, and is so arranged that it causes the valve to rise and drop evenly upon its seat.

and bottom by a 1¼-inch pipe. The upper connection enters the steam space on top of the boiler shell and the lower passes through the head at a point near the bottom row of tubes. It is customary to place the bottom of the glass about 2 inches above the top of the upper row of tubes. The gauge-cocks are for the same purpose as the water glass, and can be used in case anything interferes with the proper working of the former.

A blow-off pipe should connect with the shell at the bottom for draining the boiler. The shell at this point is reinforced by means of a metal plate ½ or ⅝ of an inch thick, riveted in place. Where the pipe is exposed to the hot gases in the back connection space, it should be protected by a cast-iron sleeve packed with asbestos or mineral wool. Other means of protection are often used; a V-shaped deflector of fire brick open at the rear, for inspection, is said to give good results.

The *steam-gauge* is a device or instrument for indicating the pressure of steam; usually it is an attachment to a boiler, having mechanism by which the steam turns a pointer on a dial bearing figures, showing the *pressure in pounds to the square inch.* Each boiler in a battery should be provided with its own gauge for indicating the pressure. This may be connected directly with the steam space by an independent pipe or may enter the top connection of the combination box. The most common varieties use either a spring, as shown in Figs. 421 and 422, or a column of mercury to act against the pressure. The pipe should be supplied with a siphon or loop which will become filled with water and prevent steam from entering the gauge.

Steam-gauges indicate the pressure of steam above the atmosphere only; the total pressure, being measured from a perfect vacuum, will add $14\frac{7}{10}$ pounds, on the average, to the pressure shown on the steam-gauge. It should also be noted that the steam-gauge finger points to zero when the steam pressure is cut off.

Fig. 423 shows an admirable method of reinforcing blow-off pipes. Owing to the frictional force exerted by the steam where the blow-off pipe is connected with the boiler serious accidents have occurred, caused doubtless by corrosion, hence a piece of boiler plate somewhat thicker than the shell of the boiler itself should be securely riveted to the shell at this point, and the hole for the entrance of the pipe should be cut in such a way that it can be properly threaded, both in the reinforcing piece and *in the shell;* the extra piece is put on particularly to strengthen the small hole that is made in the shell, and also provide a greater thickness of metal for the thread, so that when the pipe is screwed into position it may have a suitable holding power. The correct mode of construction is shown in Fig. 423. In this case the hole is threaded both in the reinforcing plate and in the shell, and when the blow-off pipe is screwed into position, a good strong joint is formed, which should be entirely safe under all ordinary conditions of operation.

Feed Pipe.—The boiler feed should be delivered in such a manner that contact between the cool water and the hot plates shall be the least possible. Various devices have been used for this

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NOTE.—A two-way cock should be used for closing the connection between the steam gauge and the boiler, and at the same time to let air into the steam-gauge. The steam should never be allowed to act directly on a steam gauge when located in cold situations where it is liable to freeze. The valve on the boiler should be closed and the water allowed to drip out, and, before the steam is turned on from the boiler, the drip on the gauge should be closed, in order that sufficient steam may be condensed in the pipe to furnish the quantity of water necessary to keep the steam from striking the gauge.

STEAM CONNECTIONS.

purpose. The more usual method is to enter the feed pipe in the front head just above the tubes, extending it to within about 2 feet of the rear head; then across and down between the tubes and shell, where the end may be plugged and the water discharged through a number of small holes drilled in the pipe. The portion passing through the front connection should be of heavy iron and the remainder of brass.

Fusible Plug.—Danger from overheating the plates of a boiler is guarded against by means of a fusible or safety plug, which consists of a brass bushing with a core of some fusible metal, which melts before an excessive temperature is reached. The steam and water blowing into the furnace will check the fire to some extent, and also give warning to those in charge. In a cylindrical tubular boiler the fusible plug is screwed into the rear head at a point about 3 inches above the upper row of tubes.

A patch screw, shown in Fig. 424, is a peculiar form of bolt for screwing a patch to a boiler. It is threaded into a boiler plate, the chamfer resting against the patch; the square head is for the application of a wrench. After the bolt is well in place the head can be cut off with a cold chisel.

A blow-down arrangement showing the piping from five boilers with each other is shown in Fig. 425. The figure is intended to be self-explanatory, showing an admirable system of connections. Attention is called to the increasing size of the pipes as they take the water from boilers 1 to 5; beginning with an inch and one-half pipe and ending with a three and one-half inch pipe leading to the drain. It will be noticed also, that the Y-branches as they issue from the boilers are of uniform size, *i. e.*, one and one-half inches.

INSTALLATION OF BOILERS.

The care and management of a steam boiler—after its setting in brick work and with all smoke, water, steam and sewer connection made—comprises three things:

1. The preparation, which includes the partial filling with water and the kindling of the fire.

2. The running, embracing the feeding, firing and extinction or banking of the fire.

3. The cleaning out after it has been worked for some time.

It is apparent that any rules or directions which might be given for one system would not apply equally to other forms of boilers and this may be the principal reason that the art is one so largely of personal instruction. Some rules and hints will, however, be given, which may prove of advantage.

It is said that no two boilers, even though they seem to be exactly alike—absolute duplicates—ever did the same, or equal service. Every steam boiler has an individuality of its own, with which the person in charge has to become acquainted, in order to obtain the best results from it.

Before lighting the fire under the boiler in the morning the engineer or fireman should make a rapid yet diligent examination of various things, viz.: 1. He should make sure that the boiler has the right quantity of water in it—that it has not run out during the night or been tampered with by some outside party; very many boilers have been ruined by neglecting this first simple precaution. 2. He should see that the safety-valve is in working order; this is done by lifting by rod or hand the valve which holds the weight upon the safety-valve rod. 3. He should open the upper gauge-cock to let out the air from the boiler while the steam is forming. 4. He should examine the condition of the grate-bars and see that no clinkers and but few ashes are left from last night's firing. 5. And finally, after seeing that everything is in good shape, proceed to build the fire as follows:

On lighting the fire put a good armful of shavings or fine wood upon the grate, then upon this some larger pieces of wood to form a bed of coals, and then a little of the fuel that is to be used while running. Sometimes it is better to light before putting on the regular fuel, but in any case give it plenty of air. Close the fire doors, and open the ash pit, giving the chimney full draft.

When the fire is well ignited, throw in some of the regular fuel, and when this is burning add more, a little at a time, and continue until the fire is in its normal condition, taking care, however, not to let it burn too freely for fear of injury to the sheets by a too rapid heating.

It is usually more convenient to light the fire through the fire door, but where this cannot be done, a torch may be used beneath the grates, or even a light fire of shavings may be kindled in the ash pit.

At the time of lighting, all the drafts should be wide open.

As soon as the steam is *seen* to issue from the open upper gauge-cock it is proof that the air is out. It should now be closed and the steam gauge will soon indicate a rise in temperature.

When the steam begins to rise it should next be observed that: 1. All the cocks and valves are in working order—that they move easily. 2. That all the joints and packings are tight.

The duties of the fireman in the routine of the day may thus be summed up:

1st.—*Begin to charge the furnace at the bridge end and keep firing to within a few inches of the dead plate.*

STEAM CONNECTIONS.

2d.—*Never allow the fire to be so low before a fresh charge is thrown in that there shall not be at least three to five inches deep of clean, incandescent fuel on the bars, and equally spread over the whole.*

3d.—*Keep the bars constantly and equally covered*, particularly at the sides and the bridge end, where the fuel burns away most rapidly.

4th.—If the fuel burns unequally or into holes, *it must be levelled, and the vacant spaces must be filled.*

5th.—The large coals must be broken into pieces not bigger than a man's fist.

6th.—When the ash pit is shallow, it must be the more frequently cleared out. A body of hot cinders, beneath them, overheats and burns the bars.

7th.—The fire must not be hurried too much, but should be left to increase in intensity gradually. When fired properly the fuel is consumed in the best possible way.

Smoke Pipe and Dampers.—The smoke connection between the boiler and chimney stack is usually made of No. 10 or 12 black iron. It may be either round or rectangular in section, although the former is preferable, especially for small sizes, and is more efficient for a given area. The larger sizes of rectangular pipe should be stiffened by rivetting angle iron in the corners.

Where two or more boilers are connected with the same smoke pipe, there should be a damper for hand regulation in each uptake, in addition to the balanced damper in the main pipe. The small dampers should be furnished with means for holding in any position desired. The main damper should be provided with roller bearing and connected with some form of reliable regulator, of which there are several makes.

SPECIFICATION OF HORIZONTAL TUBULAR BOILERS.

Horse-Power.	Diameter of Boiler in Inches.	Length of Boiler in Feet.	Number of Tubes.	Diameter of Tubes in Inches.	Length of Tubes in Feet.	Square Feet of Heating Surface.	Diameter of Dome in Inches.	Height of Dome in Inches.	Thickness of Steel in Shell of Boiler.	Thickness of Heads.	Recommended. Diameter of Smoke Stack in Inches.	Recommended. Length of Smoke Stack in Feet.	Space Occupied by Brick Setting in Feet. Height. Ft.	Height. Ins.	Width. Ft.	Width. Ins.	Length. Ft.	Length. Ins.
15	36	8	26	3	8	210	20	20	$\frac{1}{4}$	$\frac{3}{8}$	16	24	7	6	6	6	14	0
20	36	10	26	3	10	280	20	20	$\frac{1}{4}$	$\frac{3}{8}$	16	28	7	6	6	6	16	0
25	42	10	38	3	10	350	20	20	$\frac{9}{32}$	$\frac{3}{8}$	20	32	8	0	7	0	16	0
30	42	12	38	3	12	420	20	20	$\frac{9}{32}$	$\frac{3}{8}$	20	36	8	0	7	0	18	0
35	42	14	38	3	14	490	20	20	$\frac{9}{32}$	$\frac{3}{8}$	20	40	8	0	7	0	20	0
40	48	12	50	3	12	560	24	24	$\frac{5}{16}$	$\frac{7}{16}$	24	44	8	8	7	6	18	0
45	48	14	50	3	14	630	24	24	$\frac{5}{16}$	$\frac{7}{16}$	24	48	8	8	7	6	20	0
50	48	16	50	3	16	700	24	24	$\frac{5}{16}$	$\frac{7}{16}$	24	50	8	8	7	6	22	0
60	54	16	58	3	16	780	30	30	$\frac{5}{16}$	$\frac{7}{16}$	26	50	9	6	8	0	22	0
70	60	14	76	3	14	924	30	30	$\frac{11}{32}$	$\frac{7}{16}$	28	50	10	0	8	6	20	0
75	60	15	76	3	15	990	30	30	$\frac{11}{32}$	$\frac{7}{16}$	28	50	10	0	8	6	21	0
80	60	16	76	3	16	1,056	30	30	$\frac{11}{32}$	$\frac{7}{16}$	28	60	10	0	8	6	22	0
90	66	15	94	3	15	1,215	36	36	$\frac{3}{8}$	$\frac{7}{16}$	30	60	10	8	9	8	21	4
100	66	16	94	3	16	1,300	36	36	$\frac{3}{8}$	$\frac{7}{16}$	30	60	10	8	9	8	22	4
125	72	16	120	3	16	1,600	36	36	$\frac{7}{16}$	$\frac{1}{2}$	36	75	11	6	10	2	22	4
150	72	18	120	3	18	1,800	36	36	$\frac{7}{16}$	$\frac{1}{2}$	36	75	11	6	10	2	24	4

CHIMNEYS.

A chimney is an upright structure containing a passage or flue by which smoke and other products of combustion escape into the open air; they are designed not only to secure an adequate draft, but also for the diffusion in the upper air of deleterious gases. When several chimneys are carried up together the mass is called a *stack of chimneys.* The part of the chimney carried above the roof for discharging the smoke is the chimney-shaft, and the upper part of the shaft is the chimney-top or head. A *chimney-throat* is the narrowed entrance to the neck of the chimney. The draft of a chimney is the drawing or moving of a confined current of air. It is the mingling of fresh air with the combustibles that produces heat, and the draft is absolutely necessary to the operation of the furnace.

A chimney promotes a flow of air through a furnace, because the hot air contained in the chimney is lighter than the surrounding atmosphere, which consequently endeavors to force its way into the chimney from below in order to restore the balance of pressure. The only way into the chimney is through the fire-bars and furnace, and in passing through these the air maintains the combustion, and at the same time becoming itself heated, makes the action of the chimney continuous.

The above effect is produced by what is called the, 1, *natural draft;* a blast which rarefies the air above the fire is called a, 2, *blast draft;* or by blowers which compress the air beneath the fire a, 3, *forced draft.* In some recent vessels increased draft has been secured by the partial exhaustion of the air in the uptakes and lower parts of the funnels, which causes an increased flow of air from the fire-room through the furnaces; this is called an, 4, *induced draft.*

BRICK CHIMNEYS.

In proportioning chimneys, the cause of their action must be borne in mind. The column of heated gases in the stack is lighter than a similar column of the colder external air, so, in its effort to restore equilibrium, the outer air presses into the furnace. It is self-evident that an increased supply of air induces more rapid combustion of the fuel, and therefore, other things being equal, the taller the chimney the better will be the draft, and consequently more steam will be generated from the same boiler.

The outside diameter of a *brick chimney* at its base should not be less than one-tenth of its height. The circular form is preferable, as less material is used for a given area, and the wind has far less effect upon it than upon a square section.

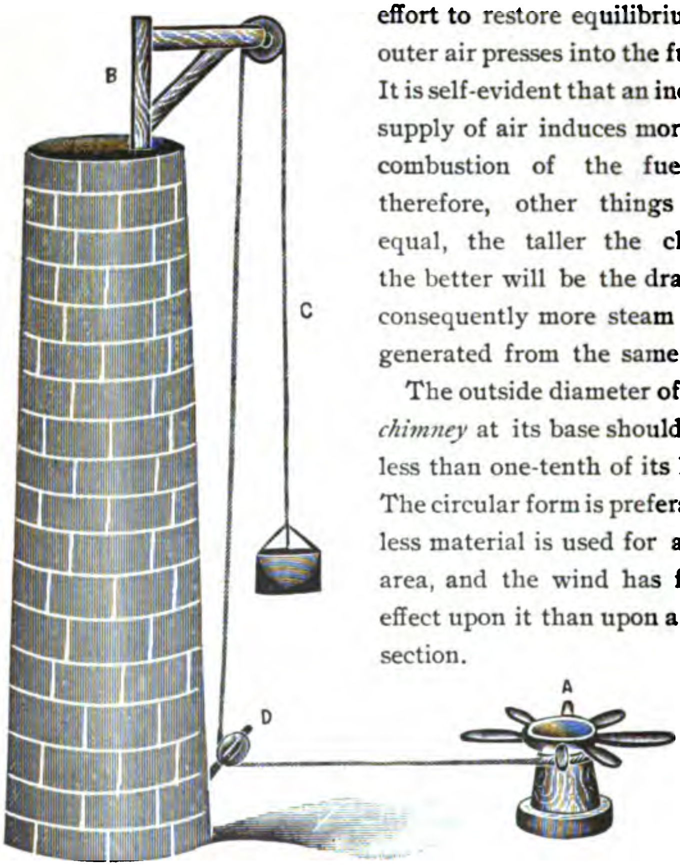

Fig. 426—See page 423.

In any case the *flue* should be circular in section. It should have a separate lining of fire brick carried up for a height depending upon the heat of the escaping gases.

"POINTS" RELATING TO CHIMNEYS.

If the gases or vapors are very hot, it is advisable to build the entire chimney of fire brick.

A common batter or slope for the sides of a chimney is ½" per foot for each side, or one in twenty-four. The thickness of brick work should be a single brick (9") for the top twenty-five feet, increasing by a half brick (4½") for each twenty-five feet from the top downwards. If the chimney be under three feet in inside diameter, the top ten feet may be half a brick only.

A less height than 100 feet is not recommended for boiler chimneys on account of the difficulty in burning inferior fuels with a short chimney. Wood and sawdust require the least draft; fine coal, culm, or slack, the most. It has been calculated that, to burn anthracite slack economically, a chimney over 170 feet high is required.

It is better that a tall chimney should stand by itself as the unequal rate of settlement between the stack and an adjoining building frequently causes breaks in the masonry.

The maximum distance from the furnace to the foot of the shaft should not much exceed half the height of the latter. The connecting flues should not be built until after the chimney is completed and has had time to settle.

Iron chimneys are frequently used instead of the more elaborate and costly structures of brick; these consist simply of iron plates bent to shape and single rivetted with lap joints, stiffening rings of angle or tee bars being added.

Fig. 426 represents a convenient method of building brick chimneys; the crane at B enables the workmen, when the brick and mortar are raised, to swing them around to the point where they are to be used. The lower part of the rope C D is connected with a wheel and axle.

DRAFT OF CHIMNEYS.

All boiler chimneys of considerable size should consist of an outer stack of sufficient strength to give stability to the structure and an inner stack or core independent of the outer one. This core is often extended up to a height of but 50 or 60 feet from the base of the chimney, but it is better to run it up the whole height of the chimney; it may be stopped off, say, a couple of feet below the top, and the outer shell contracted to the area of the core, but the better way is to run it up to about 8 or 12 inches of the top, and not contract the other shell. The core should *never* be built into or connected at its upper end with the outer stack, for there is great danger of the expansion of the inner core lifting the upper part of the outer stack and cracking the brick work.

An excess of draft can be corrected by the use of a damper or even by the closing of the ash-pit doors, but no more unhappy position for an engineer can be imagined than a deficiency of draft.

This lack is produced by 1st, too little area in the chimney-flue; 2d, by too low a chimney; 3d, by obstructions to the flow of the gases; 4th, by the overtopping of the chimney by adjacent buildings, hills or tree tops. There are other causes of failure which practice develops; hence the draft of a new chimney is very often an uncertain thing until every-day trial demonstrates its action.

The draft of steam boiler and other furnaces should be regulated below the grate and not in the chimney. The ash-pit door should be capable of being closed air tight, and the damper in the chimney should be kept wide open at all times, unless it is absolutely necessary to have the area of the chimney reduced in order to prevent the gases from escaping too fast to make steam.

"POINTS" RELATING TO CHIMNEY DRAFTS.

When two flues enter a larger one at right angles to it, opposite each other, as is frequently the case where there is a large number of boilers in a battery, and the chimney is placed near the centre of the battery, the main flue should always have a division plate in its centre between the two entering flues to give direction to the incoming currents of gases and prevent their "butting," as it may be termed. The same thing should always be done where two horizontal flues enter a chimney at the same height at opposite sides.

In stationary boilers the chimney area should be one-fifth greater than the combined area of all the tubes or flues.

For marine boilers the rule is to allow fourteen square inches of chimney area for each nominal horse power.

The draft of a chimney is usually measured in inches of water. The arrangement most commonly made use of for this purpose consists of a U-shaped glass tube connected by rubber tubing, iron pipe, or other arrangement, with some part of the chimney in such a way that the draft will produce a difference of level of water in the two legs of the bent glass tube.

In estimating the action of a chimney of a given size in producing a draft, the density, temperature, and volume of the products of combustion must be considered.

The necessary height of a chimney varies with the fuel used, wood requiring the least, then good bituminous coal, and fine sizes of anthracite the greatest. It also varies with the character of the boiler—the smaller and more circuitous the gas passages the higher the stack required; also with the number of boilers, a single boiler requiring less height than several which discharge into a horizontal flue. No general rule can be given.

RULES AND EXAMPLES RELATING TO DRAFTS.

The draft increases directly as the area and as the square root of the height. If either is assumed or determined upon the other may be found from the formulæ:

$$\frac{120\times\text{grate surface in sq. ft.}}{\sqrt{\text{height in feet}}}=\text{area in sq. inches.}$$

EXAMPLE.

What should be the size (area in sq. inches) of a 100-foot chimney with grates 5½ feet deep by 10 feet wide? Now then:

$$120\times5\tfrac{1}{2}\times10=\underline{6{,}600}$$

divide by 10 (the sq. root of 100) 660 sq. in.

660 sq. in.=26 in. square, nearly.

To find the number of cubic feet of air in a chimney.

RULE.

Multiply the length in feet by area in feet or decimals of a foot and the answer will be the contents of air in cubic feet.

EXAMPLE.

How much air will be contained in a chimney 90 feet high and 48 in. square flue?

4 × 4=16 area in feet × 90=1440 cubic feet Ans.

EXAMPLE.

If it be an iron chimney 90 feet high and 24 inches in diameter?—then

Area 24 in. (per table)=452.4 sq. in.=3.141 sq. feet

90

$282\frac{7}{10}$ths Ans.

RAISING STEEL SMOKE STACKS.

Large numbers of steel and iron smoke stacks are in use; they are much shorter lived than brick ones, owing to natural corrosion. The raising and lowering of these stacks has become a special trade. The note below is a copy of a question to one of those experts in rigging and placing iron and steel chimneys; the answer is given in his own words, which are indicated by quotation marks.

"Would suggest the following scheme for raising, if the conditions will allow: After erecting and securely guying the pole, place the stack upon the ground with the lower end as near to the pole as the walls of the building will permit; attach the permanent guys at their proper places, and make your sling fast to the stack at a point about one-third of its length from the top end, rig the tackle and run the down-haul around the drum of a crab.

"Pine timbers six inches square (the pole not to be over 40 feet long), properly spliced, would safely carry the weight if free from knots or weak spots. A good straight telegraph or telephone pole 40 feet in length and, say, 5 inches through at the top, would be better.

"Take care that the hitch on the pole is made high enough so that the stack can be raised to an upright position without bringing the blocks together.

"As the stack is raised, it can be guided and held upright by the guys which may be temporarily secured.

"The stack now stands erect upon the ground at the side of the building. Make another hitch at a lower point upon the stack

---

NOTE.—"Will you please inform me as to the quickest and safest way to raise a smoke stack, 60 feet long and 42 inches in diameter, weighing 8,000 pounds? The old stack is to be taken down, the time being limited to ten hours by contract. Stack is to be raised 12 feet to foundation. How heavy should spliced square pine timbers be, of which pole is to be made?"

sufficient to allow the same to be raised to its maximum height, and secure the lower block of the lifting tackle fast to this hitch.

"Place a sling around the bottom of the stack, and make fast a tackle to pull from a point directly in line with stack and pole. Proceed to raise stack, keeping it in a vertical position and just clear of the building by the aid of this last tackle and the guy wires, until the bottom of stack is above the roof, when the lower tackle may be slacked off and the stack moved in toward the pole and lowered to its foundation.

"The stack which is there now may be removed in precisely the reverse manner.

"Three sheave blocks would be about the proper thing to use."

Figs. 427 and 429 show a brick chimney that costs no more than a self-supporting steel stack. It is very stiff and stands up against wind pressure in good shape. The *inside shell* is 12 inches thick at the bottom and 8 inches at the top; it does not reach quite through the top.

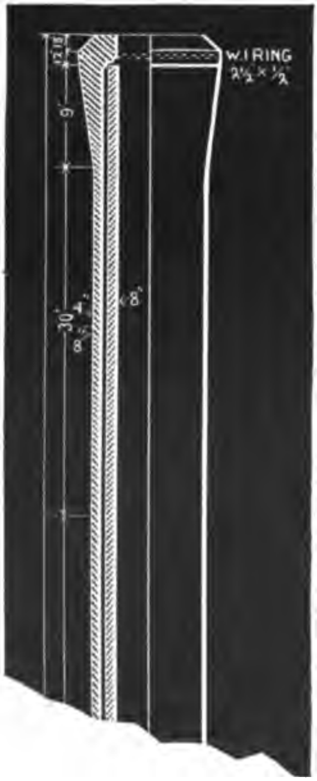

Fig. 427.

The *outside shell* is 12 inches thick at the bottom and 8 inches during the latter part, except at the enlargement of the top as shown. Commencing at the top, there are 18 inches for the

PLAN AND DIMENSIONS OF BRICK CHIMNEY.

bevel. This has a cast-iron cap with rabbetted joints, so that no water can get under the plate. Copper bolts, $\frac{7}{8}$ inch diameter, are built into the chimney at the top, and when the cap is in place these are rivetted. The cap reaches down 4 inches inside of the chimney and 4 inches over the base of the bevel. The square part is 12 inches and the slope is 9 feet.

Below this for 30 feet the chimney is straight, and from that point to the bottom the batter is $\frac{2}{16}$ of an inch per foot on each side. As shown on the plan at the base, buttresses are built into the out-

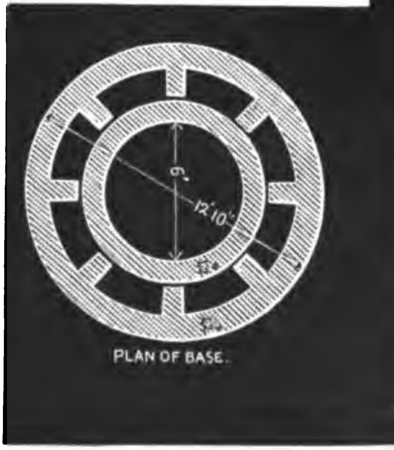

Fig. 428.

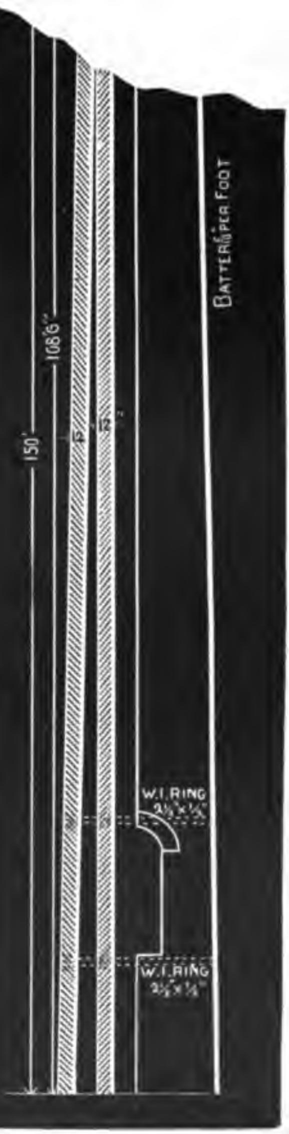

Fig. 429.

side shell and extend as high as possible. They should not come within 3 inches of the inner shell at any point.

Above and below the opening for the flue and at the top of the chimney there is a 2⅛x⅛-inch iron band built in next to the outer course of brick, and every 10 feet there is a band, 1⅛x¼ inch, built in the same way, so that the chimney is thoroughly banded, and yet they do not show.

A leaning chimney at Earnest, Pa., is reported to have been straightened in a novel manner. The stack is 122 feet high, 11 feet square at the base, tapering somewhat at the top and weighs 400 tons. The walls are 36″ thick. The top was found to be leaning 45″ from the vertical line. To right the chimney 10⅛″ of brick work was removed from the foundations on three sides.

As the bricks were removed, square blocks of wood were inserted, one after another, until three sides of the structure rested on the blocks. Between the blocks substantial brick piers 6⅛″ high were built, leaving a space 4⅛″ between the top of the piers and the bottom of the undermined brick work. The blocks were then set on fire and kept burning evenly. If one burned faster than the others, the fire on that particular block was checked, so that all were made to burn uniformly, and as the blocks were reduced to ashes, the stack slowly righted.

As the top gradually swung back through the 45″ arc, small fissures appeared near the base. In every groove a steel wedge was driven to maintain the weight of the walls. The entire work consumed one day, and the reduction of the wooden blocks to ashes required one hour.

PART TWO

OPERATING

For "Erecting" see page XVII.

This eminent man of science was born in Woburn, Massachusetts, in 1753 and died at Auteuil, near Paris, in 1814. He was one of the first Americans to win a title in Europe; and one of the very few whose efforts at reform have received practical reward in this life. He took the side of the mother country during the revolution and was knighted. In 1784 he made a Continental tour, and entered the service of the King of Bavaria in the curious capacity of general reformer.

BENJAMIN THOMPSON, "Count Rumford."

He remodelled the whole military system of the country, and organized a plan for employing the poor in useful pursuits. His official duties, however, did not materially interfere with the prosecution of his scientific pursuits to which he had been devoted from his early youth. In 1795 he visited London where he remained until 1804, when he definitely settled in France, where he passed his time in the steady pursuit of those researches relating to heat and light and the economy of fuel.

STEAM ENGINE.

Nothing is so essential to an erector as that he should know the names and general uses of every part of the machinery to be brought together and put in satisfactory operation—in a word—*to be installed.*

To *install* means to establish in a place or position ; an *installation*, as used in the succeeding pages of this book, denotes the introduction of machines, apparatus, and accessories for doing any specified work, and also the establishment of an *entire plant*, as an electric-lighting plant. The definition of *machinery* includes not only the parts of a machine or engine, but also a number of machines and kindred appliances taken collectively, or again, a complex system of mechanisms.

A brief examination of the table of contents of this work will more clearly show the idea here intended.

The installation of the power-producing apparatus, as steam, gas, water, electricity, wind, is not intended to be minutely described, part for part, but rather to make clear the principal and general methods used in erecting and adjusting them.

The foregoing remarks are intended as a short introduction to part II of the volume: the principal machine to be installed and put in operation is the steam engine; upon its successful erection depends the ultimate success of the whole plant.

The steam engine is a prime mover designed to convert heat into work by allowing steam to expand behind a working piston ; a form of heat engine in which steam is the working fluid.

It is made in a great variety of forms. A steam engine is *stationary* when mounted and fixed in permanent form, *portable* when mounted with a boiler on wheels so as to admit of being moved about to any point where the power is to be utilized, *semi-portable* when of small size, with the engine arranged as a fixture on top of the boiler, and *locomotive* when furnishing power to move itself about and to draw loads.

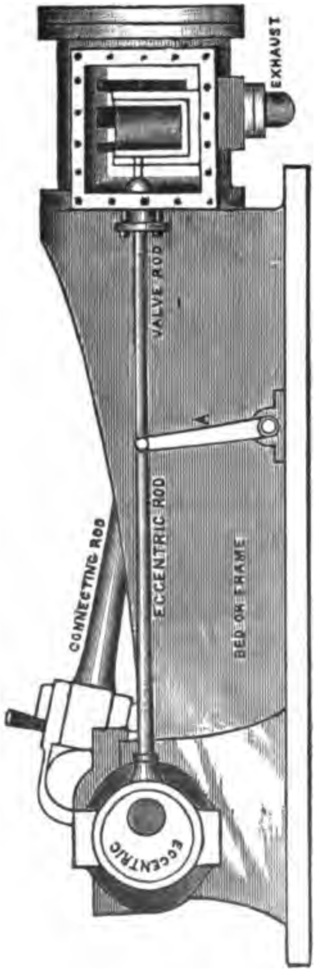

Fig. 427.

Many hundreds of types or forms of steam engines have been made, but all are operated on the principle that *the power or energy comes from the heat, and the heat comes from the burning of the coal.* None of the power which drives an engine comes from the steam, water or the engine itself.

The most numerous pattern of the steam engine made is the common slide valve stationary engine, because it is the simplest and the cheapest; such as is represented in Figs. 427-9.

Its valve gear or valve motion consists of the eccentric and its strap, the eccentric rod, the valve rod guide A, the valve rod or valve spindle, and the valve V, these parts controlling the admission of steam to one side of the piston, and the exhaust from the other.

THE STEAM ENGINE.

The piston, piston rod, cross-head, connecting rod, crank, crank shaft, main shaft or driving shaft, and the fly wheel constitute the driving or power-transmitting mechanism.

The steam side of the piston is that against which the steam is pressing, as side S in Fig. 429. The exhaust side, E, of the piston is that on which the steam is passing out or exhausting.

The cylinder is the most important part of a steam engine, because within its compass is accomplished the change of energy of the fuel into the work the engine is designed to perform; it is the most approved form, because, 1st, the circular form is the strongest; 2d, it is easier to make and repair; and 3d, it would be difficult to keep a rectangular piston steam-tight.

The *steam piston* is a circular disc fitted to the bore of the cylinder, which receives and transmits the pressure of the steam to the other moving parts of the engine.

The designs of pistons are innumerable, according to the varying size of the cylinders they are designed to fit, but there are two things necessary for all: they should be steam-tight and yet so adapted to the bore of the cylinder that they move with the least possible friction. Besides, they should be strong enough to meet the unequal strains of the pushing of the steam and hold the end of the piston rod immovable.

The *cross-head* is the device which forms the connection between the piston rod and the connecting rod; it is similar to the elbow

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NOTE.—In the elementary form of the steam engine the cylinder served the triple purpose of boiler, engine and condenser. In after history the boiler and condenser were made into separate parts to form and condense the steam while the cylinder is used for its true office—the conversion of the energy in the steam into mechanical power.

PARTS OF THE STEAM ENGINE.

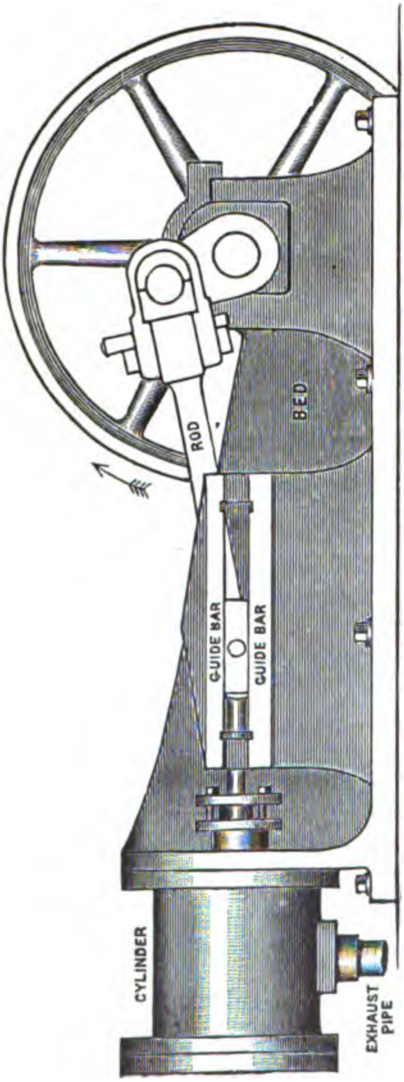


Fig. 428.

of the human body; it guides the piston rod so as to keep it straight in spite of the bending motion caused by the angularity of the connecting rod.

The *connecting rod* is the device used between the crank and the cross-head; the centre of the crank-pin end of the connecting rod moves in a true circle, while the centre of the opposite end has the reciprocating—back and forth—rectilinear motion.

There are two principal kinds of connecting rods, the "strap ended" and the "solid ended"; the latter wear the best, but are more difficult to get on and off the engine. The ordinary length of connecting rod is six times the length of the crank, or *six cranks*, as it is commonly termed.

The *guide bars* of an engine require to be set exactly in line with the axis

ECCENTRICS.

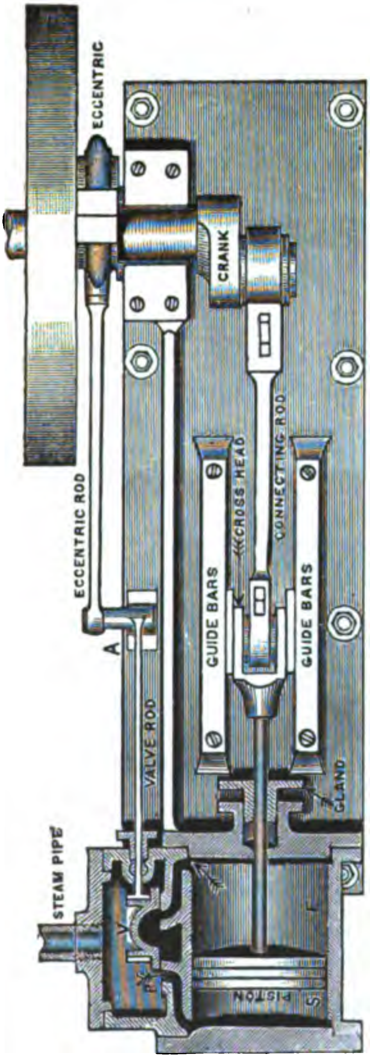


Fig. 420.

of the cylinder bore, so that they may guide the piston to travel in a straight line. They should be an easy sliding fit to the cross-head guide. Piston-rod packing, composed of fibrous or similar material, is used for making a fluid-tight fit, as between the piston head and its cylinder. Piston rods are also frequently packed with metallic packing.

The *crank pin* is that portion of the engine which receives the greatest stress and special care must therefore be given to its design and lubrication.

The *eccentric* is a species of a crank; its peculiarity being that the "crank pin" is increased to such a size that it exceeds the diameter of the shaft, the distance between the centre of the crank pin and the centre of the shaft being "the radius of eccentricity," which is the distance between the centre of the disc and centre of the shaft.

THE AUTOMATIC SHAFT GOVERNOR.

The *governor* is the ruling spirit of an engine. The use of a governor of any kind is to supply more or less energy to the engine as needed. Where the changes of load are liable to be very great, or where absolute uniformity of speed of rotation is not essential, the regulation is frequently performed by hand, as in the case of locomotives, hoisting engines, etc. Where the speed remains constant, however, as in the case of factory engines, etc., the prime mover is always equipped with a governor which will automatically vary the supply of water, gas or steam, as the case may be, in proportion to the demands made upon it and in such a manner as to keep the speed of rotation constant, under varying loads.

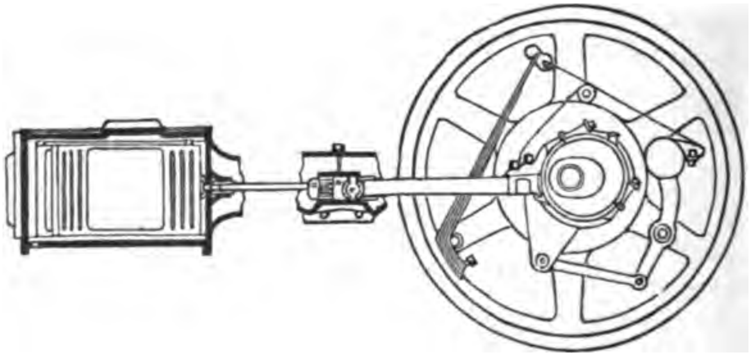


Fig. 430.

The governor for a common D valve engine regulates the engine speed by varying the opening in the bore of the pipe through which the steam passes from the boiler to the steam chest, leaving a wider opening in proportion as the engine runs

SINGLE, DOUBLE AND BELL CRANKS.

slower, and reducing the opening when the engine runs faster. Assuming the engine to be running at its slowest, or its load to be so great that a full supply of steam is required in order to keep the engine up to its proper speed, the governor will be open at its widest, so that all the further action the governor can have is to reduce the steam pipe opening, and thus cause the pressure in the steam chest to be less than that in the steam pipe.

This action is called wire-drawing the steam, and the governor is called a *throttling governor*. The speed of the engine is also controlled by altering the steam admission to suit the load known as automatic expansion—which is effected by the governor during the progress of each revolution of the engine.

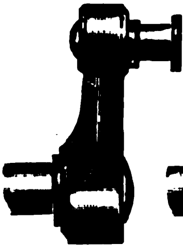


Fig. 431.

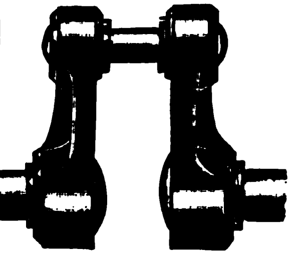


Fig. 432.

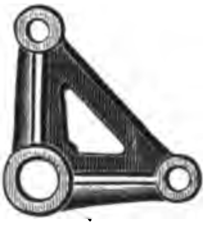


Fig. 433.

Fig. 430 shows an *automatic shaft governor* so called because it is mounted on the shaft and revolves with it. The eccentric which actuates the slide valve is carried on the governor. As the speed increases the throw of the eccentric is shortened thus securing an earlier cut-off as the lap is of course constant.

CAP SCREWS, BOLTS AND STUDS.

The *steam engine crank* is simply a lever of the first order, either attached to the main shaft or forged in one piece with it. By its means *the reciprocating motion of the piston is translated into the circular or rotary motion of the shaft.*

Fig. 431 represents what is known as *the single* or overhung crank, sometimes also termed a "side hitch" crank. Fig. 432 shows a *double* crank, called a centre crank as it has often bearings on both sides. The next figure, 433, shows a *bell crank.* See note.

Bolts, cap screws, and kindred articles used in the making and assembling of the steam engine and other machines of like nature are seldom called by their right names.

Says a writer in *Machinery*, writing upon this subject: "In fact, I am inclined to think that these parts are more frequently indicated incorrectly on drawings than otherwise, and one has but to tend stock room for a short time to observe the confusion regarding the sizes, names, standards, etc., of these small but important pieces. It requires only a brief comparison of the standards adopted by the different bolt and screw manufacturers to place one in the position where I should be glad to have someone straighten out the work for me." Figs. 434 to 436 are nuts; these are furnished by the makers rough, with tops trimmed and chamfered or not, as desired; semi-finished (faced on the bottom); or finished and case-hardened.

Fig. 434 is a *plain hexagon* nut, Fig. 435 is a *cupped hexagon* nut, Fig. 436 is a *plain square* nut, Fig. 437 is a *cupped square*

NOTE.—These cranks were originally used, in a diminutive size in connection with wire moved door bells, hence their name, but, the same principle of operation has been extended to cranks used in mining pumps, etc., each arm measuring twenty or more feet. Their use is to *convert horizontal into vertical motion* or the contrary.

SEMI-FINISHED NUTS.

nut. These articles are furnished by the makers with the holes the exact size designed to fit standard machines or nut tops; the cuts are introduced here simply to call attention to the proper names of the nuts.

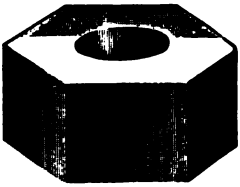


Fig. 484.

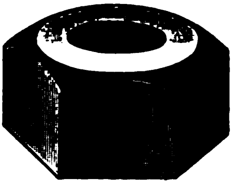


Fig. 485.

The figures on page 442 represent *machine screws*—so called—because they are used in metal, others are used in wood and are called *wood screws*. The parts of the common screw are the *head* (usually grooved to receive a screw driver or shaped to fit a wrench), the *barrel* or *stem*, the *thread* and *point*.

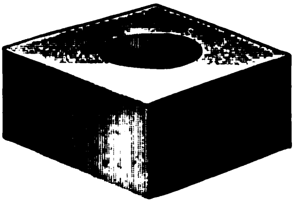


Fig. 486.

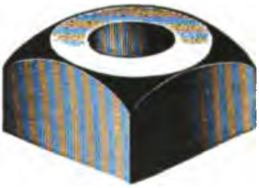


Fig. 487.

Machine and set screws are usually threaded their whole length to one of the standard bolt threads. Those used as set screws have *the last three or four threads turned off the point*, which is cupped to afford better contact with the piece which it locks.

Wood and lag screws are provided with a flattened thread, at right angles to the stem, together with a gimlet point, for easy penetration of the timbers which they fasten.

MACHINE SCREWS AND STUDS.

Figs. 438 and 439 represent *set screws*, one with a hexagon and the other with a square head. They are tightened with a spanner, monkey wrench, etc., and derive their name from being used to prevent bolts or shafts from turning, as the shaft inside a pulley opening.

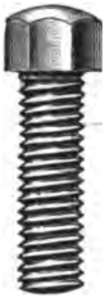


Fig. 438.

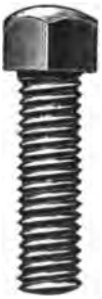


Fig. 439.

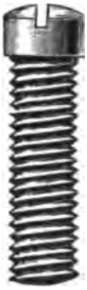


Fig. 440.

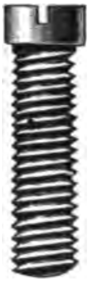


Fig. 441.

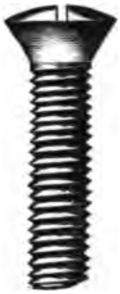


Fig. 442.

Cap screws are tightened by means of a screw driver, and derive their various names from the shape of their heads. Cap screws are made in sizes of diameter that are even quarters, eighths or sixteenths of an inch and the number of threads per inch conform to the United States standard. Machine screws are made in sizes agreeing with the machine screw gauge, the number of threads conforming to the machine screw standard. The shape, size or style of head has no significance whatever in determining whether a screw is a cap screw or a machine screw.

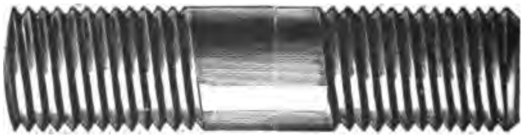


Fig. 443.—See page 444.

U. S. AND WHITWORTH SCREW THREADS.

On the other hand, the main difference between a *cap-screw* and a *machine-bolt* is in the size and shape of the head. Hexagon head cap-screws have heads approximately as long as the diameter of the screw and their short diameters about ¼ inch larger than the diameter of the screw. Square head cap-screws have correspondingly long heads, also, the short diameter being about ⅛ inch larger than the diameter of the screw, for ordinary sizes. Machine-bolts have shorter heads, as a general thing, and of a diameter nearly as large as that of the United States standard bolt. A cap-screw is used to bolt one piece, which is not threaded, to another piece which is threaded, while a machine-bolt is more often used as a through bolt, to hold together pieces, neither of which are threaded.

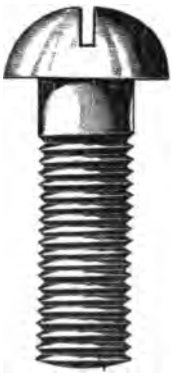


Fig. 444.

Any bolt threaded nearly to the head and which is intended to be used in a tapped hole without a nut on the end is properly called a tap-bolt. Some manufacturers make tap-bolts with heads like those of hexagon or square head cap-screws and others adopt other styles. Fig. 443 represents a *stud bolt;* this is used largely in steam engine work in steam chests. Figs. 446–448 represent three forms of screw threads.

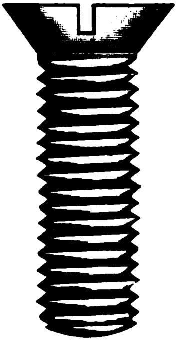
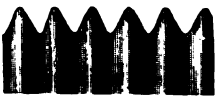
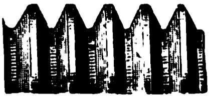
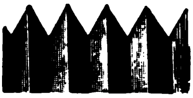


Fig. 445.


WHITWORTH.
Fig. 446.


U. S. STANDARD.
Fig. 447.


V THREAD.
Fig. 448.

CAP SCREW HEADS.

The *Whitworth* thread, Fig. 446, has an angle to its sides of 55°, and one-sixth of the thread is rounded off top and bottom; this is the standard thread in most countries.

The Sellers' or *United States thread*, Fig 447, encloses an angle of 60° between its sides, with one-eighth of the thread flattened at top and bottom. This thread is becoming more and more the standard in the United States.

The *V-thread*, Fig. 448, has an angle of 60°, slightly rounded at top and bottom, so that its depth is 0.8 of the pitch instead of 0.866, as it would be with a full V-thread. This is the style of thread universally followed for *pipe work*, and is more easily produced than either of the other types. Tables of the proportions of these threads will be found in other parts of the book.

A stud, such as is shown in Fig. 443, must be *a tight fit in the place into which it screws*, as otherwise it will loosen in its place when the nut is unscrewed. It seems necessary, therefore, either to have the stud bottom in the hole, or else to have it screw up to the end of the thread. The latter is preferable, because it is not always possible to drill and tap holes all of the same depth.

Fig. 440 shows a very common form known as the *filister* or *filletster;* the *countersunk*, Fig. 445, is often used where a smooth surface is requisite. The *round* head, also known as the *cheese* head, Fig. 441, is frequently met with, and so is the dome-shaped head, Fig. 444, known by some as the *button* head, and by others as a *snap* head on account of its likeness to a snap rivet.

Fig. 442 is a combination of countersunk and filletster head.

ENGINE FOUNDATION.

In dealing with this subject the sections in the early part of the book relating to foundations, piling, etc., may be re-studied to advantage.

It is the first essential that a steam engine be placed upon a solid, stable foundation; this direction applies to all machines, as freedom from *vibration* is thus secured.

The foundation must have sufficient mass to absorb the vibrations caused by the motion of the various parts of the engine so that they may not be transmitted to adjacent machinery.

The footings of the foundation should be spread out over a sufficiently wide area to prevent settling. This is largely dependent upon the supporting power of the different soils, figures relating to which have been tabulated on page 62. When calculating the loads bearing upon the soil, the weight of the piers themselves must not be neglected; and when, as sometimes happens, their depth in the ground becomes very considerable, the base area may require to be increased.

The depth to which the foundation is carried must be far enough below the surface to be free from the influence of the loads borne by neighboring soil, and also from frost.

A reasonable *batter* or slope to the footings should be given, similar to that illustrated in Fig. 30, page 44. One to two

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NOTE.—Foundation drawings might readily be made to represent the requirements more fully than many of them now do, and this is not the less true, because no matter how completely they may present the needs of the case, something must still be left to the discretion of those upon whom the execution of the work devolves, and by whom the character of the ground upon which the structure is to rest must be considered.

BED FOR GIRDER TYPE ENGINE.

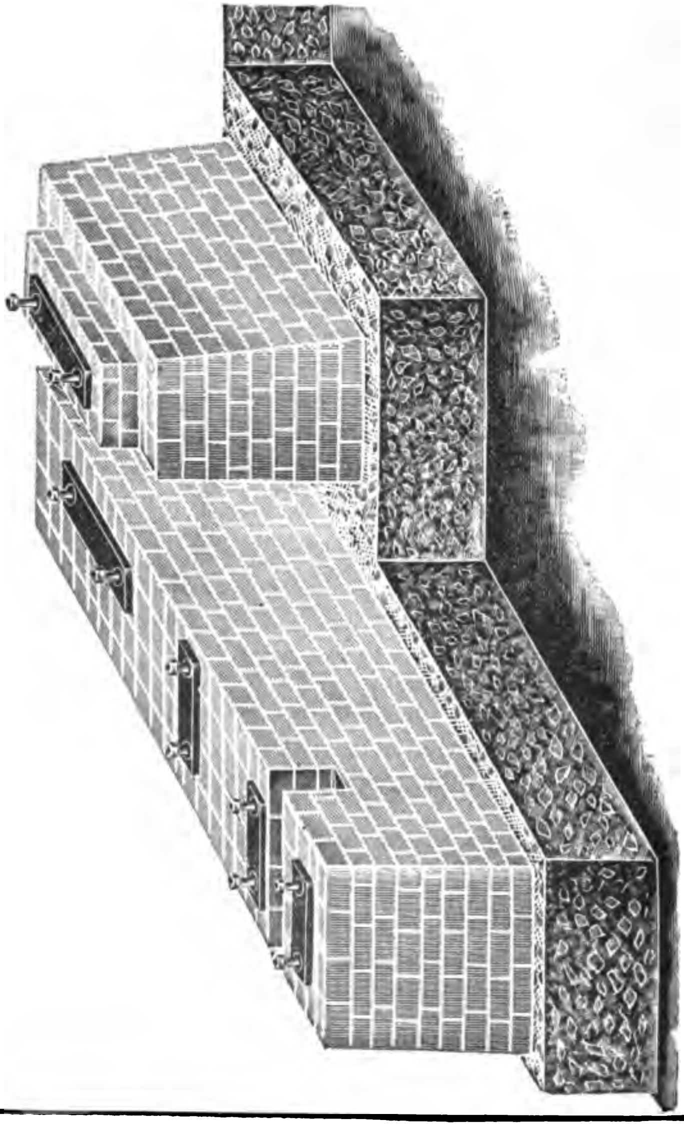

Fig. 449.

inches to the foot will be found sufficient for a horizontal engine, but, owing to the more concentrated weight of the vertical form, a batter of 3 inches to the foot may be given at the sides, and from 4½" to 6" per foot at front and back, to counteract the rocking influence of centrifugal force. With brick beds, the lower courses being laid in header bond, this splaying is easily effected, as may be seen by reference to Fig. 89 on page 109, and to page 111.

The foundation should be completed at least fifteen days before the engine is placed on it, by which time, if properly laid, the brick-work will be practically one mass. All sunken parts of foundations, such as fly-wheel pits, should have drain pipes. Foundations for hydraulic cylinders should be so constructed as to permit easy access to their supply pipes.

The accompanying illustrations show three different shapes of foundations.

Fig. 449 is the form used for *girder frame engines*, similar to the well-known Corliss type. A layer of concrete is first spread over the bottom of the excavation, on top of which the brick-work is laid. The fastening of the anchor bolts is shown, consisting of a heavy cast-iron plate, laid in the brick-work, and drilled and threaded for the bolt; the top is formed of cast-iron plates, on which the pedestals rest.

NOTE.—In cases in which it is impossible to provide adequate foundations immediately beneath a column, what is known as the *cantilever construction* is resorted to. This simply means that the column is carried upon the end of an overhung beam, which in turn is supported as near the column as practicable, the reaction at the other end being taken usually by building it in beneath another column capable of fully resisting its upward tendency. Notable examples of this construction occur in some of the many-storied buildings, where the columns are required to come close to the property lines, while the foundations must not project beyond them.

BED FOR TANGYE TYPE ENGINE.

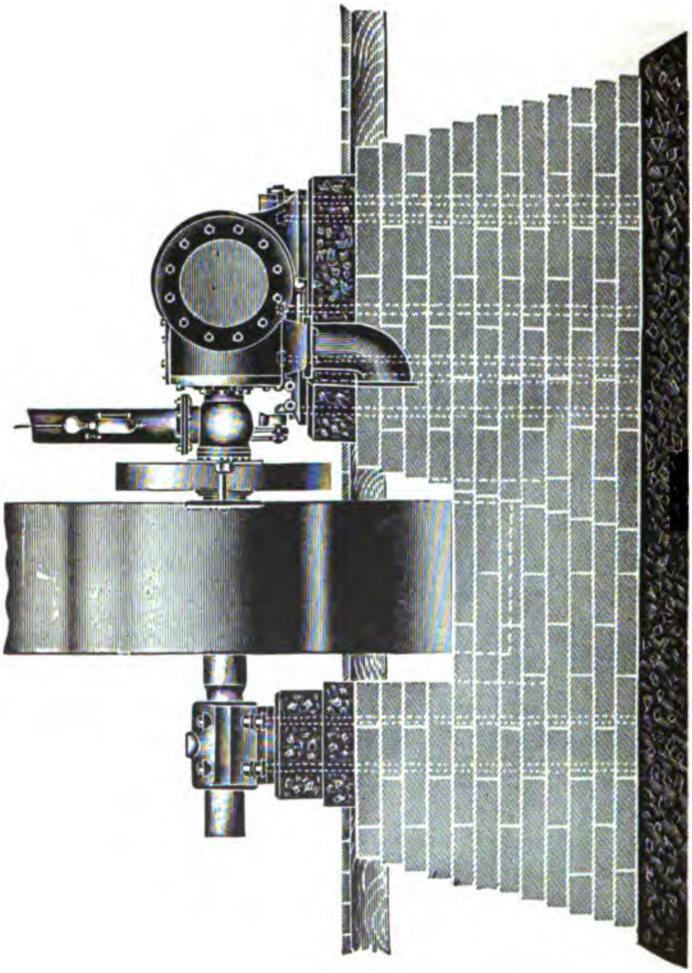

Fig. 450.

BED FOR HIGH SPEED ENGINE.

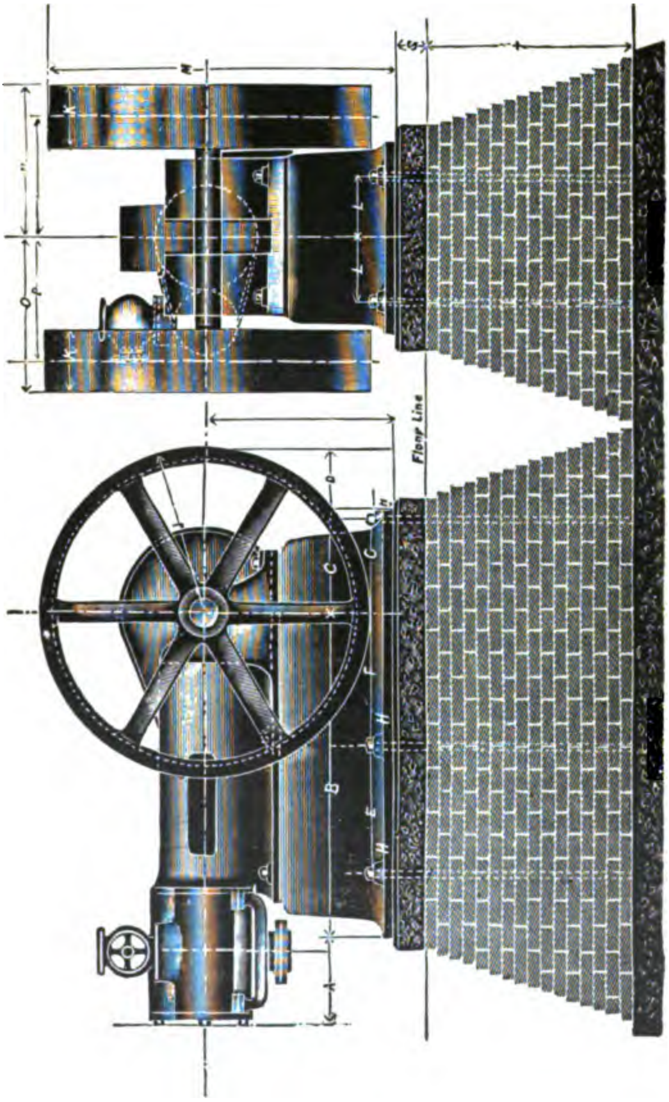

Fig. 452.

Fig. 451.

TEMPORARY TIMBER FOUNDATIONS.

Fig. 450 shows a form of foundation which differs from the first described by a brace being run across, combining the outboard pillow block part with the main body of the foundation, and the bolts being masoned into the brick-work, the foot ends passing through a broad washer. This foundation is generally used for *Tangye bed* engines, which usually run at medium speed. A foundation often used for high speed, self-contained engines is shown in Figs. 451 and 452; it simply consists of a solid body of brick-work.

It is very often the case that a timber foundation is found to be the best, or indeed, the only practicable foundation for an engine or for a heavy machine. The number of semi-portable steam engines used to run dynamos during engineering work of more or less duration makes it desirable to have a method of holding the machine down which will permit of "pulling up stakes" on short notice and settling again promptly at a greater or less distance. See Fig. 453 for an ingenious manner of doing this. In such cases, heavy beams may be used for bed timbers, and to these the engine is held down by bolts, or, indeed, by long lag screws; in all cases the thread and bearing surfaces of heads, washers, etc., should be smeared with grease and graphite before running up. The lengthwise timbers to which the engine is bolted may very easily be secured to heavy cross timbers (to give both weight and lateral rigidity) by dovetail wedges of yellow pine.

A noteworthy example of the application of engineering principles to foundation construction is shown in the employment of *the inverted arch.* This is used in cases where high walls, or walls carrying heavy loads, require to have openings of large size, such as for main entrance, and where it is desired to prevent the weight of the wall above from coming as a concentrated load upon a limited area on either side of it. An inverted arch is built beneath the ground level connecting the two sides of the opening and having the same effect, so far as the pressure upon the soil is concerned, as a solid wall of equal weight. Where the depth of foundation is insufficient to form the inverted arch, a strong girder is sometimes used.

Foundations carrying great weights should always be built in steps, the width increasing towards the bottom. It would, perhaps, be a better form of expression to say that the lower courses should present sufficient area to the soil to enable it to sustain the superimposed weight. Footing courses for foundations should be proportioned with due regard to the character of the ground upon which they rest, and also for the weights which they are to carry.

The best construction is one in which all the bolts can be got at, not only on top but at the bottom. The neatest way to do this is by means of tunnels and manholes by which all bolt pockets can be reached. When the foundation is small this end can sometimes be attained by *bolt pockets* extending to the outside of the brick-work, which can be reached by digging if necessary. In the case of tunnels, it is a good plan to drain them. The bolt pockets should be deep enough to allow the bolts to drop below the finished level of the foundation. This permits the placing of the bolts and then moving the casting over them, after which it is a simple matter to push the bolts up and guide them into position, and a little easier than fishing for the hole in the washer that cannot be seen. The bolt boxes (sometimes iron pipes are used, but wood is just as good, and easier to remove if necessary) should be much larger than the bolts, and

ENGINE FOUNDATIONS.

never less than 3 inches square. This allows for final adjustment, and may save considerable expense, as an extra ½ inch in the box is cheaper than chipping out brick. These holes are later filled with sand to within an inch or two of the top.

To facilitate replacement, the bolts are also made pointed upon the lower end and readily find their own way into the holes in the foundation washers.

The brick for foundations should be hard, tough and sound; and roughness is not a bad quality, as it gives the cement a better grip.

Fig. 453 represents the ordinary crowbar drawn to a point and tempered, which is very useful for drawing small piles or posts.

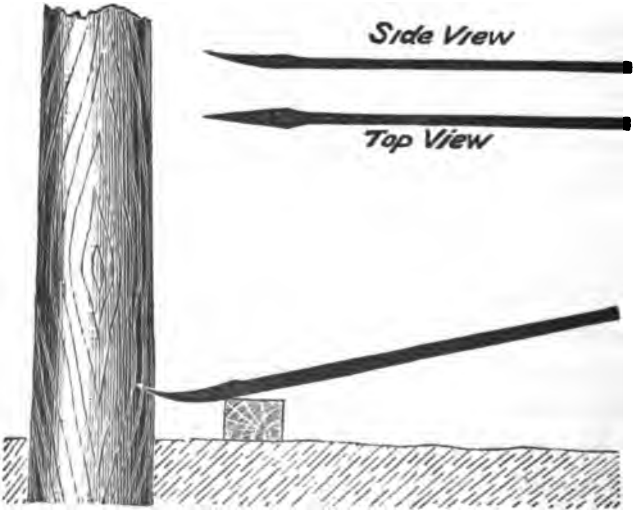

Fig. 453.

ENGINE VALVES.

The distribution of steam within the cylinders of an engine is controlled by *valves* of varying forms, which fall into three broad classifications; (1), *Slide valves*, which travel to and fro over a plane or curved surface, and regulate the passage of the steam through ports in that surface; (2), *Rotary valves*, in the cylindrical form, which vibrate within a cylindrical seat, as in the Corliss engine, also admitting or exhausting the steam past their edges; (3), Disc or *drop valves*, of forms more or less like an ordinary stop valve, which are raised from or lowered upon their seats to regulate the passage of the working fluid, such as are fitted to large pumping engines.

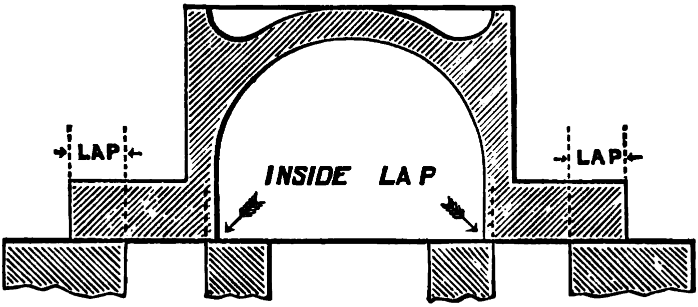

Fig. 454.—Valve with outside and inside lap.

The following four figures are intended to exhibit the elements of slide-valve design, showing *lap*, *lead*, and *travel*. The proportioning of slide valves has been a matter of experiment since the days of Watt. The majority of the engines that have ever been made have been fitted with this form of valve.

SLIDE-VALVE DESIGN.

Taking first the common slide, or *D-valve* as it is termed from its section (⋂), its parts and properties will be readily seen from Fig. 454. Should the outer edges of the valve coincide with the edges of both steam ports, or be "*line and line*," as it is termed, such as shown in Fig. 455, steam will be carried to the end of the stroke.

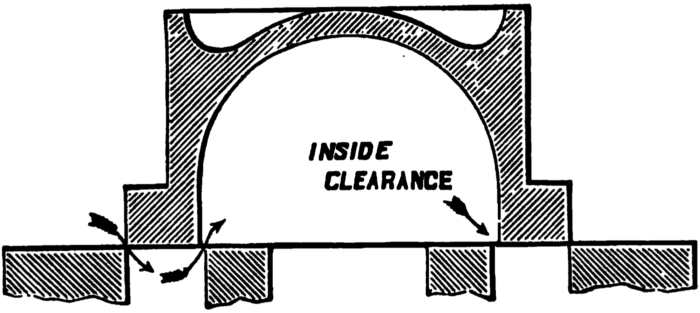

Fig. 455.—Valve without lap and with inside clearance.

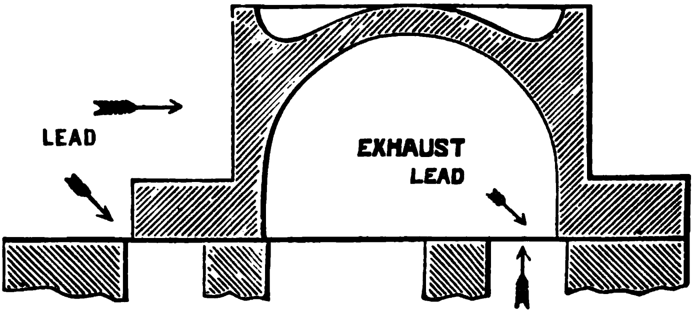

Fig. 456.—Valve showing outside and inside lead.

To procure expansion, *lap* is added to the outer edges of the valve as in Fig. 454; the eccentric, which in the former case was 90° in advance of the crank, is moved through a further angle so

SLIDE-VALVE DESIGN.

that the edge of the valve is in the position shown in Fig. 456, giving an opening to steam before the piston has completed its previous stroke,—this pre-admission is termed the *lead* of the valve.

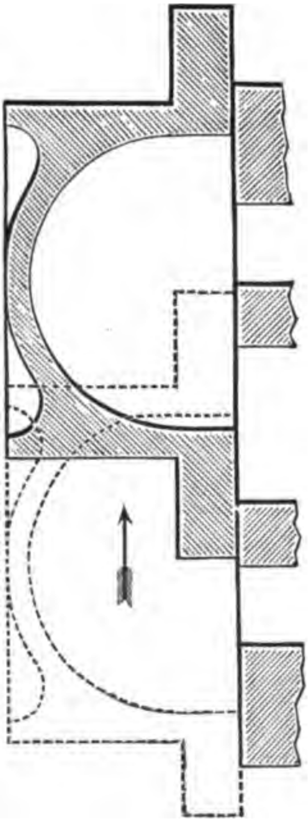

Fig. 457.—Valve showing maximum travel.

The amount by which the other port of the cylinder is open to exhaust, as shown in Fig. 456, may be termed *exhaust lead.*

The full movement of the valve is known as its *travel*, and Fig. 457 represents its position at either extremity of the stroke.

The travel of the valve is, of course, equal to twice the throw of the eccentric, and also equals twice the lap + the amount of opening of each port to steam. In designing a valve gearing, the necessary port opening is first determined, and all the other proportions calculated from it as a basis.

Owing to the angular advance necessitated by the lap, communication is established between the cylinder and the exhaust passage through the internal cavity of the valve at a point before the completion of the pressure stroke.

NOTE.—This must not be confused with what is known by some engineers as the *lead of the eccentric*, this latter dimension being more properly known as *angular advance.*

DOUBLE-PORTED VALVE.

This early opening to exhaust is known as *release*, and the exhaust continues until the valve has reached a point corresponding to that of release in the opposite direction, when the exhaust is closed, thus occasioning what is known as *compression* or *cushioning*. The steam is imprisoned in front of the advancing piston, thus forming a cushion to absorb the inertia of the moving parts, bringing the piston gradually to rest before it starts on its next stroke.

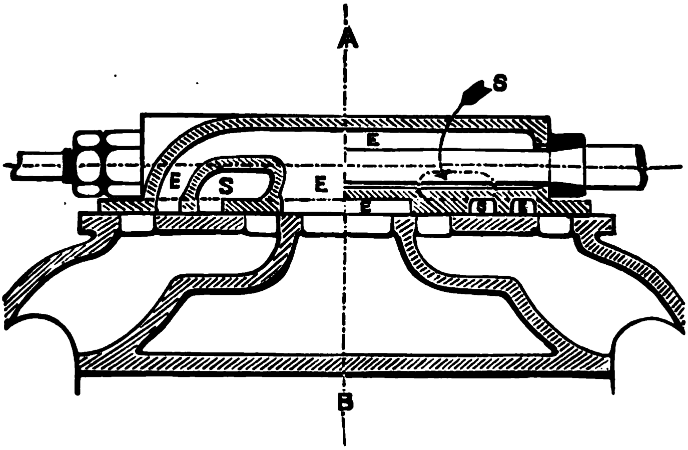

Fig. 458.

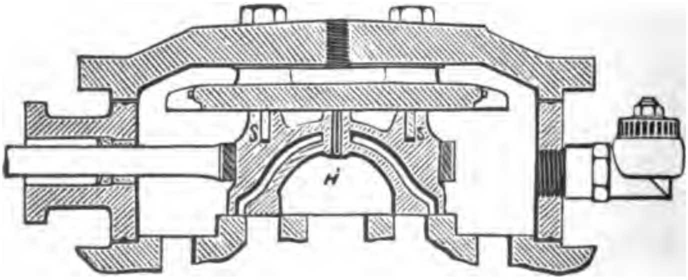

Fig 459

BALANCED VALVE.

With slow-moving engines it is necessary to increase the amount of the compression by adding *inside lap* to the exhaust edges as in Fig. 454, but with high-speed engines it is frequently found difficult to get the steam out of the cylinder fast enough, and so these edges are pared away, forming what is known by engineers as *minus* or *negative inside lap*, or occasionally termed *inside clearance.* This opens communication between the two ends of the cylinder at certain points of the stroke, but that is not important with the high speed.

As the travel of the valve is the direct measure of the work of the eccentric, engineers try to shorten it as much as possible. This is accomplished by providing more than a single admission for the steam, single-ported valves being regarded as unfit for cylinders above the moderate diameter of 24 inches. Fig. 458 represents the *double-ported valve* which is used for medium-sized engines, a treble port being used for cylinders of still larger diameters.

On account of the extent of surface exposed to steam pressure by these large valves, recourse is often had to *balancing*, or relieving as much of the back of the valves as possible from this pressure which imposes great friction on the valve. Rings or planed strips are held up against a plate or the steam chest door and prevent the access of steam to the area which is enclosed by these means. A cock communicates either with the atmosphere or condenser to prevent any accumulation of pressure within the balanced surface.

The typical balanced valve, illustrated in Fig. 459, has found much favor among locomotive engineers, but like all this class of valve, requires careful design and excellent workmanship to

THE ALLEN VALVE.

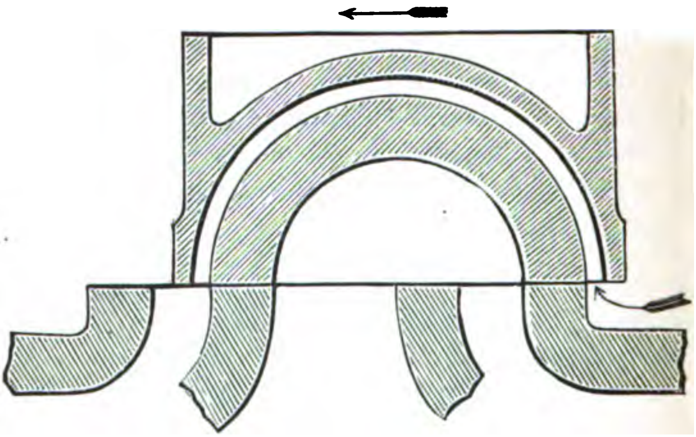

Fig. 460

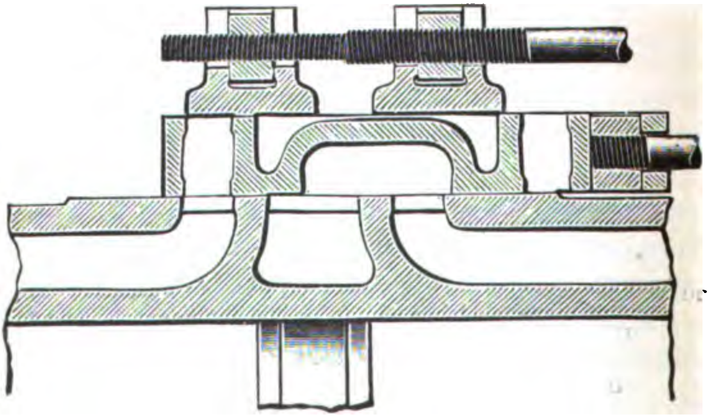

Fig. 461.

make it effective. It will be noticed that a cored hole communicates from the exhaust cavity to the balanced area, thus ensuring the pressure of exhaust steam alone on the back of the valve.

A simple means of obtaining double admission with but a single port is seen in the *Trick* or *Allen valve*, shown in Fig. 460, much used on locomotives, small marine cylinders, and stationary engines of moderate power. A certain amount of balancing is also claimed for it. The steam passes to the cylinder port from the opposite end of the valve through the passage cast in its back, as well as past its normal edge. The process of exhausting is the same as with a D valve.

Owing to difficulties attending the removal of the exhaust steam from the cylinder, it is impractical to attempt an earlier cut-off than about *half stroke* with an ordinary slide valve and eccentric. To give economical rates of expansion, two valves are employed, each having a separate eccentric; the *expansion* or *cut-off valve* being a grid or plate, working on the back of the *main valve*, which serves as its seat, the steam ports being passages *through* the main valve, which latter controls exhaust alone. In such a case the governor acts upon the expansion valve through a link, shortening the travel and cut-off as the load lightens.

The *Meyer valve* illustrated in Fig. 461 is employed where necessary to vary the expansion by hand. The expansion valve consists of two flat plates controlled by a right and left hand screw on the valve stem; the tail end of the stem is carried through a stuffing box, and is rotated by means of a hand wheel, shorter cut-off being obtained by turning the stem so that the plates become further apart, which is the same as increasing the lap.

THE CORLISS VALVE.

The *piston valve*, Fig. 462, is a cylindrical slide valve working in a seat curved to suit it. It is consequently *balanced*, and is considered the least objectionable form of valve that can be used; it cannot leave its face when dirt or grit is deposited upon it, and its chief defects are that unless carefully designed and fitted, it is not as steam tight as ordinary valves.

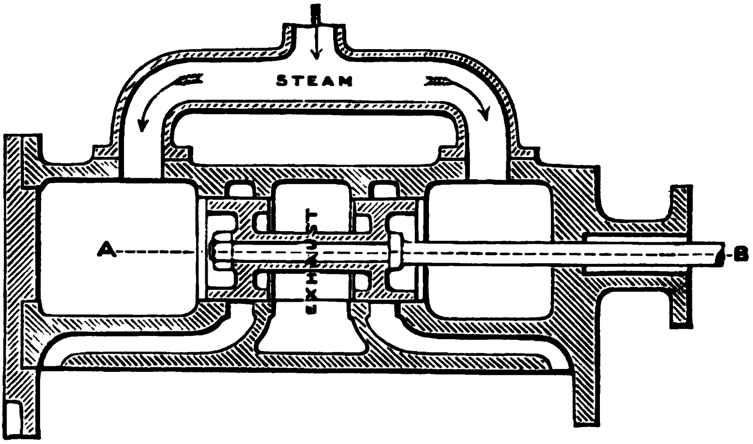

Fig. 462.

The *Corliss valve*, shown in Fig. 463, is the outcome of an effort to produce a valve gear which would have the following advantages:—(1), minimum of power to actuate the gear; (2), smallness of clearance spaces; (3), adaptability to close governing; (4), good steam opening combined with quick cut off and free exhaust. It avoids many of the disabilities of the slide valve and is a favorite gear on account of the sharp outline of its indicator diagram. Some of the largest and best known engine-

CORLISS VALVE PORTS.

builders in the world have modified and improved the original design of valve and operating mechanism until it has reached a state of great perfection.

In the illustration, Fig. 463, steam enters the cylinder casing by the opening for the steam pipe flange (7), and flows around the cylinder barrel in the annular passage (5), thus jacketting the cylinder. It gains admission past the steam valve (1), through the admission port (3), into the bore of the cylinder (9). After performing its work upon the piston the steam passes through the exhaust port (4) and exhaust valve (2), into the exhaust passage (6), finally escaping to the atmosphere or condenser through the eduction pipe (8); the cylinder cover (10) is not jacketted in this instance.

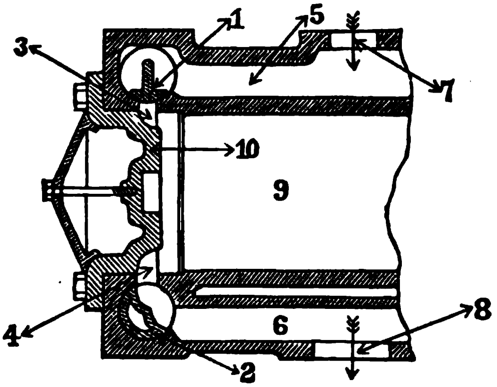

Fig. 463.

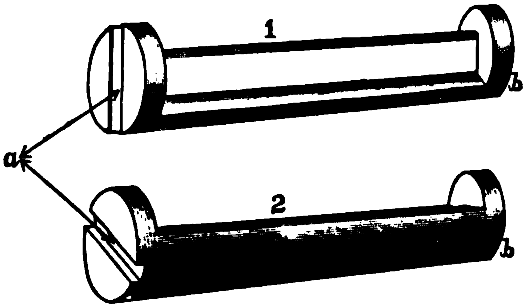

Fig. 464.

THE DROP VALVE.

In Fig. 464, these valves are shown in perspective on an enlarged scale, (1) being the steam valve and (2) the exhaust valve. The recesses *a*, cut across the face of the circular end of the valves, are to receive a T-shaped head of the valve stems, which transfers the rotary motion of the latter to the valves, and still allows the valves to be withdrawn from their respective chambers by removing the covers on the front side of the engine.

It also enables the valves to leave their seats, if forced by water or over-pressure, and to follow up near without bending the valve stem. The steam valve is riding upon the port, which connects the steam chest (5) with the cylinder, and is held to its seat by steam pressure, while the exhaust valve is held to a port connecting exhaust chamber (6) with the exhaust valve chamber; thus the steam pressure always holds it to its seat.

Table Showing Lap and Lead of Valves of Corliss Engine.

Cylinder Diameter in inches.	Wrist Plate on its Centre.		Steam Lead, Engine on Centre.
	Steam Lap.	Exhaust Lap.	
8, 10 & 12.	3-16"	1-32"	1-32"
14, 10, 18 & 20.	¼"	1-16"	1-32"
22, 24, 26, 28 & 30.	5-16"	3-32"	3-64"
32, 34 & 36.	⅜"	⅛"	1-16"

NOTE.—The *drop valve*, originally used altogether with large pumping and winding engines, has been long in favor with Swiss and German engineers, and in many directions is fast supplanting the more delicate Corliss gear. Its range of adaptability extends from large central station engines indicating 10,000 H. P. down to the fast-running motor car with its 1,000 revolutions per minute, and is evidently a type of valve to be reckoned with in all future engineering progress. *This valve is not illustrated.*

SETTING SLIDE VALVES.

The necessary preliminary operation is to ascertain the exact dead centres of the engine, in other words, to mark the crank-positions when the piston is at the extremity of its stroke in either direction.

First, bar the fly wheel round until the engine has made about ⅞ of its outward stroke, and scribe a fine reference mark on guide and crosshead shoe. At the same time make a mark on either the crank-web, disc or fly-wheel rim, according to the type of engine, at a point in about the same plane as the centre of the cylinder.

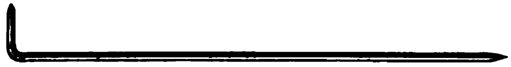

Fig. 465.

To achieve this, a trammel, as shown in Fig. 465, must have been first prepared; this consists of a piece of ¼″ or ⅜″ tool steel rod, of suitable length corresponding to the size of the engine, with some three inches bent at one end to a right angle with the body, and either end ground to a fine point. In fact, it exactly corresponds to the bent scriever of a scribing block.

A permanent centre punch mark is made upon the engine framing to receive the straight end of the trammel—with a vertical engine, this will be on the column or condenser; in a hori-

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NOTE.—That part of an engineer's duties which causes him real anxiety, and wherein he is most liable to make mistakes, is in the setting of the steam valve gear. The trouble is made greater by the variety of engines, which involve changes in the valve setting. The assistance of an expert is justifiable in this particular operation, especially by any one who does not have the advantage to be gained by the use of an indicator. All engine builders, it may be added, are more than ready to give minute directions for the setting of the valves of their own pattern of machine.

zontal engine, it may be at a convenient point on the bed-plate in wake either of the disc crank or of the fly wheel. A ring of small punch marks should be made around this permanent mark, to easily identify its position for future occasions, especially after painting.

The mark made by the bent end of the trammel on fly wheel or crank, simultaneously with the mark on the guide and crosshead, should be faint.

Having made the two reference marks, the engine is turned, *still in the same direction*, over the centre until the marks on guide shoe and guide exactly coincide once more, showing that the piston has travelled just as far from the dead centre in the opposite direction.

A second mark is made with the trammel upon the crank or fly-wheel rim ; and the distance between this mark and the one first made is carefully halved and a permanent centre punch mark made at the midway point.

The same procedure must be followed for the cylinder-end or top centre, and for the other cranks if the engine be compound or triple expansion.

At any time, the engine may now be set on the outward dead centre, turning the engine until the distance between the centre pops on the crank and framing is exactly gauged by the trammel.

NOTE.—*The reciprocating parts of the engine,* such as the piston and piston rod, with its different connections, can be readily over-strained if the piston comes in contact with water in the cylinder. While immediate breakage may not result, dangerous fractures of material are liable to occur when the engine becomes heavily loaded.

SETTING SLIDE VALVES.

The reference marks on the guides should be scribed in faintly on a surface scoured with emery cloth, as a permanent mark is not needed there, and besides would only occasion confusion with the reference marks usually put on for purposes of ascertaining the clearance between the piston and the cylinder cover.

With an engine of any size, the makers usually supply a table of the laps and leads of the various slide valves, and, as these have been carefully calculated from a large experience, it is unwise to alter the valve setting, in these particulars, unless for some very special reason.

The wearing and letting together of the parts of the valve gearing, however, alter the position of the valve relative to the face upon which it works; therefore some adjustment of the lead must be made at the time of an overhaul, but always in conjunction with carefully taken indicator diagrams.

Where the slide valve is retained on the spindle by two pairs of lock-nuts, as in many small engines, the careful setting of the valve, after overhaul, is a matter of the first importance, and the following method is that usually adopted.

A number of small wooden wedges are provided, some four to six inches long, depending upon conditions, care being taken to have the taper on one side only. Some wedges should taper from half an inch down to "nothing" in the length, others (for use with a low-pressure engine) from $\frac{1}{4}''$ or $\frac{5}{16}''$ to $\frac{3}{4}''$ in the same distance.

When the steam chest cover is removed, the engine is placed on either centre, as previously explained, and, taking a suitable wedge, the engineer chalks its tapered side, and tries the lead of the valve at each side of the port. The chalk takes up a mark from the edge of the steam port, the flat back being towards the valve, but wherever practicable, a line should be scratched on the wedge with a knife blade or fine scriber.

The mean of the two measurements is the lead at that end of the cylinder, and is easily read by laying the rule across the thickness of the wedge.

The process is repeated at the other end of the stroke for the same cylinder, and for each other cylinder that may be in the engine. The slide valves may then be taken out for overhaul, with perfect confidence that a gauge has been established to replace them in exactly the same position when closing up.

The lead given to engines varies considerably, and is decided arbitrarily by the designer; on the top of the H. P. engine, in large marine jobs, it may be only $\frac{1}{64}''$, while in fast running naval engines, $\frac{5}{16}''$ to $\frac{3}{8}''$ may be given with a cylinder of the same dimensions. For L. P. engines of great size and weight, as much as an inch may be given, the amount altogether depending upon speed of revolution and the amount of inertia of the reciprocating parts.

In *direct connected* valve gear it is generally necessary to give more lead and less lap to the slide valve at the crank end of the cylinder, in order to neutralize the effect of the angularity of the connecting rod, which tends to make the cut-off earlier at that end than at the other.

Where the engine is fitted with a rocking shaft, as in the usual American type of locomotive, the unequal cut-off is neutralized by slightly altering the angle of the two levers or arms on the shaft, and equal laps and leads are in consequence obtained.

BATTENS.

A great convenience to the engineer is found in the ***batten*** or ***lath***, as seen in Figs. 466-7. They are planed true and square, measuring some three inches in width by $\frac{5}{8}''$ thick, and of a convenient length.

They are marked by laying one of each pair on the cylinder face, and scribing fine lines upon it to correspond with the edges of the various bars. The usual practice is to paint the space representing the bars ***black*** and the divisions representing the various ports or openings *white*. Fig. 466 shows its completed appearance.

Its companion is similarly scribed off from the face of the slide valve, as it lies upon its back on the engine room floor, and it is painted white for the central cavity and black for the bars in the valve, as seen in Fig. 467.

By sliding one batten over the other the engineer sees exactly what takes place during the travel of the valve, and these simple appliances become absolute necessities in dealing with piston valves having inside admission. The use of battens in that case permits the engineer to test the steam lead of his valves by measuring the position of the exhaust edge, relatively to the bushing in which it works.

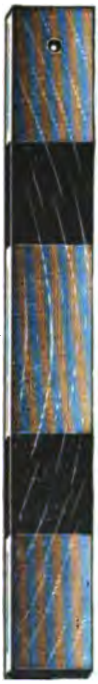

Fig 466.

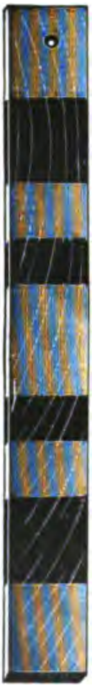

Fig. 467.

The battens should be kept as a record, and have the name of the cylinder written upon them. Similarly, a flat should be filed on the side edge of the trammel, Fig. 465, and lettered *centre*

CORLISS VALVE GEAR.

trammel or an equivalent description, so that these gauges may be kept as carefully as the indicator.

The use of the *steam-engine indicator*, where it is skilfully and intelligently applied, in the setting of the "slide" and other valves, is, beyond question, a valuable aid in adjusting steam valves. The object of the instrument is to record the *pressures that are in the cylinder at certain points of the stroke*, and from this find, first, the action of the valve gear, and, second, the distribution of pressure.

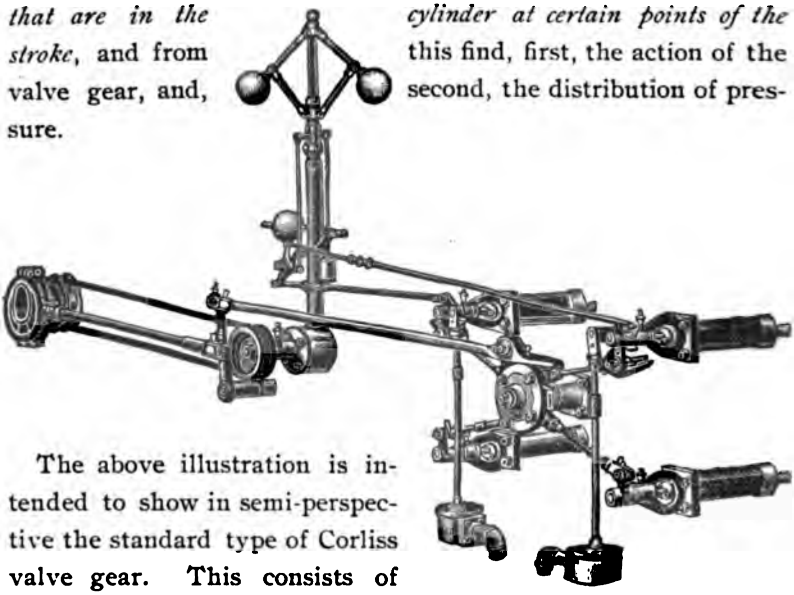

Fig. 468.

The above illustration is intended to show in semi-perspective the standard type of Corliss valve gear. This consists of four cylindrical valves, operated by a central swing or wrist plate. Two valves are placed at each end of the cylinder; the uppermost ones admit the steam, while the lower ones exhaust it out into a detached passage below the bottom of the cylinder. The admission valves are *tripped* from the eccentric at a point in the stroke determined by the governor, and closed by springs, giving a sharp cut-off. The directions for setting this valve follow:

DIRECTIONS FOR SETTING CORLISS VALVES.

The setting of the valves is not a difficult matter when, on the wrist plate, its support, valves and cylinder, the customary marks have been placed for finding the relative positions of wrist plate and valves.

Now, when the bonnets of the valve chambers have been taken off, there will be found a mark or line S′ on the end of each steam valve S coinciding with the working or opening edge of each valve; other lines TT′ will be found on each face of the steam valve chamber coinciding with the working edges of the steam port. The exhaust valves and their chambers are marked in a similar way, *i. e.*, the line E′ on the end of each exhaust valve coincides with the working edge of the valve, and the lines RR′ on the face of each exhaust valve chamber coincide with the working edges of the exhaust port.

On the hub of the wrist plate will be found a line Y coinciding with the centre line KK; lastly, there are three lines, X, Z, X, on the hub of the wrist plate support, placed in such a way that when the line Y coincides with the line Z, the wrist plate will stand exactly in the centre of its motion, and when the line Y coincides with either of the lines X, X, the wrist plate will be at one of the extreme ends of its travel.

In setting the valves, the first step will be to set the wrist plate in its central position, so that the lines Y and Z will coincide, and fasten the wrist plate in this position by placing a piece of paper between it and the washer L on its supporting pin. Now set the steam valves so that they will have a slight amount of lap, that is to say, the lines S′ must have moved a little beyond the lines T; the amount of this lap depends much on individual preference and experience; it ranges from $\frac{1}{16}$ to $\frac{1}{4}$ inch for small engines, and from $\frac{1}{4}$ to $\frac{5}{16}$ inch for comparatively large engines. This lap is obtained by lengthening or shortening the rods M by means of the adjusting nuts.

Now place the exhaust valves E, by lengthening or shortening the rods N by means of the adjusting nuts, in a position so that the working edges will just open the exhaust ports, or, in other words, place the lines E′ and R in line with each other. Some engineers prefer a slight amount of lap, others prefer a slight opening of the exhaust ports when the valves are placed in this position; under these conditions the lines E and R cannot be in line, but will stand apart, as indicated in the illustration; the

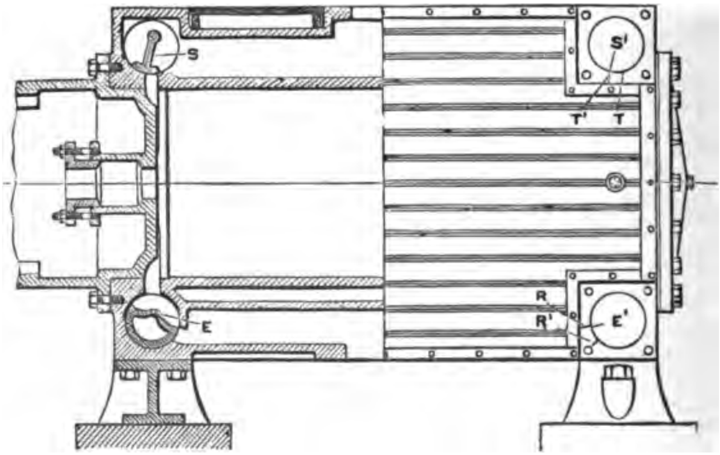

Fig. 469.

distance between these lines will, of course, be equal to the desired amount of opening; for small engines it is about $\frac{1}{16}$ inch, and for larger engines may be increased to $\frac{3}{16}$ inch, but in any case the amount of this opening should be less than the lap of the steam valves, otherwise there will be danger of blowing through.

The paper between the wrist plate and the washer on the supporting pin should now be taken out, so that the wrist plate connected to the valves can be swung on its pin.

The next step will be to pay some attention to the rocker arm, as in Fig. 470. Set this arm in a vertical position by means of a plumb-line, and connect the eccentric rod to it; then turn the eccentric around on the shaft, and see that the extreme points of travel are at equal distances from the plumb-line. To secure this a little adjustment in the stub end of the eccentric rod may be necessary. Now connect the hook rod I to its pin on the wrist plate, and again turn the eccentric around on the shaft, and thus determine the extreme points of travel of the wrist plate. If all parts have been correctly adjusted, the line Y will coincide with the lines XX at the extreme points of travel; if this is not the case, the hook rod will have to be adjusted at its stub end so as to obtain the desired equalized motion of the wrist plate.

The next step will be to set the valves correctly with the position of the crank, as in Fig. 470; to do so the lengths of the rods M and N must not be changed, but the following mode of procedure should be followed: Place the crank on one of its dead centres, and turn the eccentric loosely on the shaft in the direction in which the engine is to run, until the steam valve nearest

DIRECTIONS FOR SETTING CORLISS VALVES.

to the piston shows an opening or lead of $\frac{1}{32}$ to $\frac{1}{8}$ inch, according to size of engine, the smaller lead, of course, being adopted for small engines. After the proper lead has been given to this valve, secure the eccentric and turn the shaft with eccentric in the same direction in which the engine is to run until the crank is on the opposite dead centre, and notice if the opening or lead at this end of the cylinder is the same as on the other steam valve; if not, shorten or lengthen slightly, as may appear necessary, the

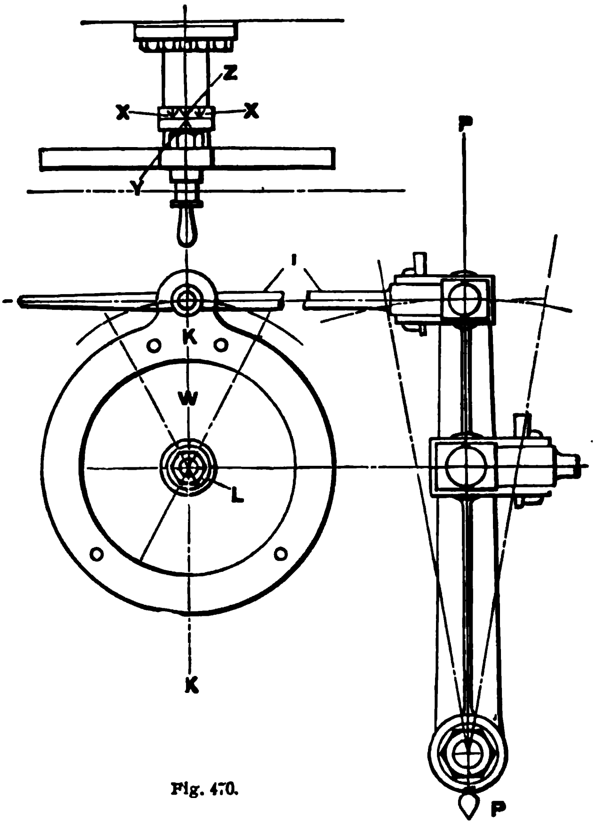

Fig. 470.

connection between wrist plate and eccentric: of course, much adjustment in the length of these connections is not admissible without setting the valves with reference to the wrist plate.

The only thing which remains now to be done is to adjust the cam rods G. To do so, secure the governor balls in their highest position and disconnect the hook rod from wrist pin; lengthen or shorten the cam rods G, so as to bring the detachment apparatus into action, swing the wrist plate back and forward and make such adjustment in the rods G as to permit the steam valves to be released when the steam port has been opened about ⅛ inch. This adjustment is for the purpose of keeping the engine under the control of the governor, in case, for some reason or another, the load on the engine is suddenly thrown off, so that the valves are not opened at all when the governor is at its highest position. After this adjustment the governor balls should be placed in their lowest position. The releasing gear is constructed in such a manner as to close the steam valves automatically, in case the belt leading to the governor should be broken.

To set the cut-off even, proceed as follows: Block up the governor where it stands when an average load is on the engine and mark on the guides the extreme travel of the cross-head. With the governor blocked up move the engine slowly, either by hand or by admitting a very little steam, until the valve is tripped, and note the exact distance travelled by the cross-head up to this point. Turn the engine to the other centre, hook up the valve and repeat the process on the other stroke. If the distance travelled by the cross-head is not the same in both cases lengthen one point of cut-off and shorten the other until the

DIRECTIONS FOR SETTING CORLISS VALVES.

travel of the cross-head is exactly the same on both strokes, up to the point where the valves are unhooked.

The dash-pot rod should be adjusted in length so the steam valve arm, resting thereon, when the dash-pot plunger is home, or at the bottom of the pot, is in such a position that the latch is sure to hook over the latch stud and the stud lies midway between the latch die and the closing shoulder. This will insure on the one hand the positive engagement of the latch, and on the other hand prevent the shoulder from jamming down upon the latch stud. If the dash-pot rod is too short, the latch will not hook on.

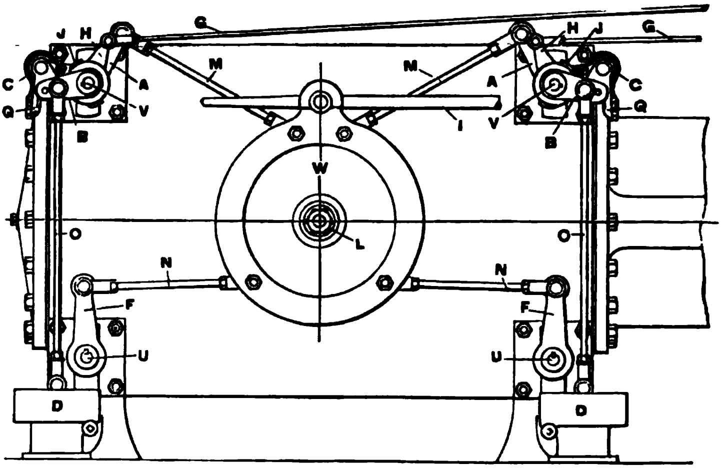

Fig. 471.

The dash-pot is provided with a leather packing in the vacuum plunger underneath the dash-pot proper. This should be kept moist and in good condition. To spread the packing, introduce some liners of paper inside the flange on cup leather. When

DUPLEX PUMP VALVES.

leather is adjusted, the pot will work promptly and softly; the valve in the air opening is to regulate the amount of air cushion by adjusting the screw in the escape hole. The regulator gag-pot is used on Corliss engines to prevent over-sensitiveness of the governor and its response to trivial changes.

The illustration 472 is a sectional view of one side, or half, of the *Worthington duplex pump;* the valve E is an ordinary slide valve; the motion of this valve is controlled by a vibrating arm F which swings through the whole length of the stroke; access for cleaning the suction chamber C is had by removing the hand hole plate at the side and in the centre. The discharge valves are reached through the hand hole at D.

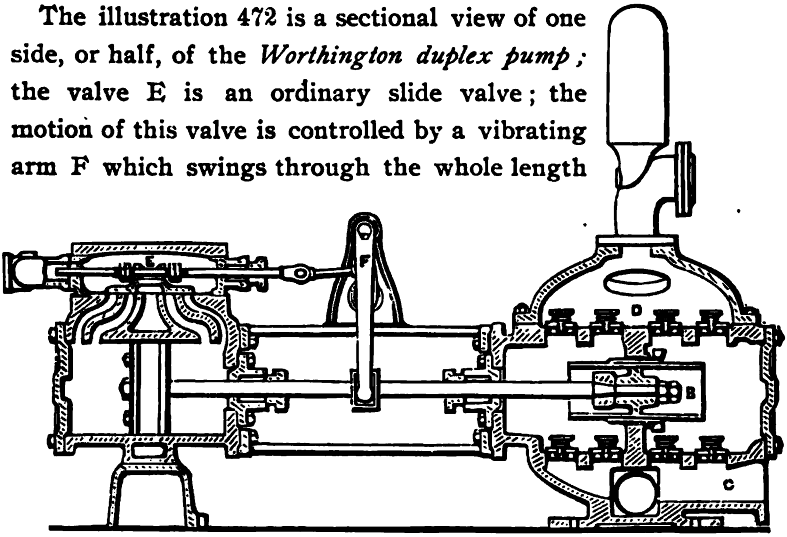

Fig. 472.

Note.—*The valve motion is the prominent and distinguishing characteristic of the Worthington duplex pump.* Two steam pumps are placed side by side and so combined that one piston acts to give steam to the other, after which it finishes its own stroke and waits for its valve to be acted upon by the other pump before it can renew its motion. This pause allows the water valves to seat quietly, and removes any harshness of motion. As one of the steam valves is always open, there is no dead point, therefore the pump is always ready to start when the steam is admitted.

SETTING THE VALVES OF THE DUPLEX PUMP.

The following rule applies to nearly all duplex pumps of the Worthington type. The valves are usually of the common "D" valve type, working on the cylinder iron, or bronze seats, and suitably "set." Sufficient cushion at the end of each stroke is provided by separate valves in the ports.

Reference is made in the rule below to the illustration on page 475.

1, *Locate the steam piston in the centre of the cylinder.* This is accomplished by pushing the piston to one end of its stroke against the cylinder head and marking the rod with a scriber at the face of the stuffing-box, and then bringing the piston in contact with the opposite head; 2, *divide exactly the length of this contact stroke.* Shove the piston back to this half mark, which brings the piston directly in the centre of the steam cylinder, F; 3, *perform the same operation with the other side;* 4, *place the slide valves*, which have no lap, *to cover all the ports*, E; 5, *pass the valve stem through the stuffing-box and gland.* The operation of placing the pistons in the centre of their cylinders will bring the levers and rock shafts in a vertical position; 6, *screw the valve stem through the nuts* until the hole in the eye of the valve stem head comes in a line with the hole in the links, connecting the rocker shaft; then put the pins in their places; 7, *adjust the nuts on both sides of the lugs* of the valves to leave about ¼" or ⅛" lost motion on each side.

This process of adjustment being performed with both cylinders, the steam valves are set. In short the travel of the two valves is simply equalized.

LINK MOTION.

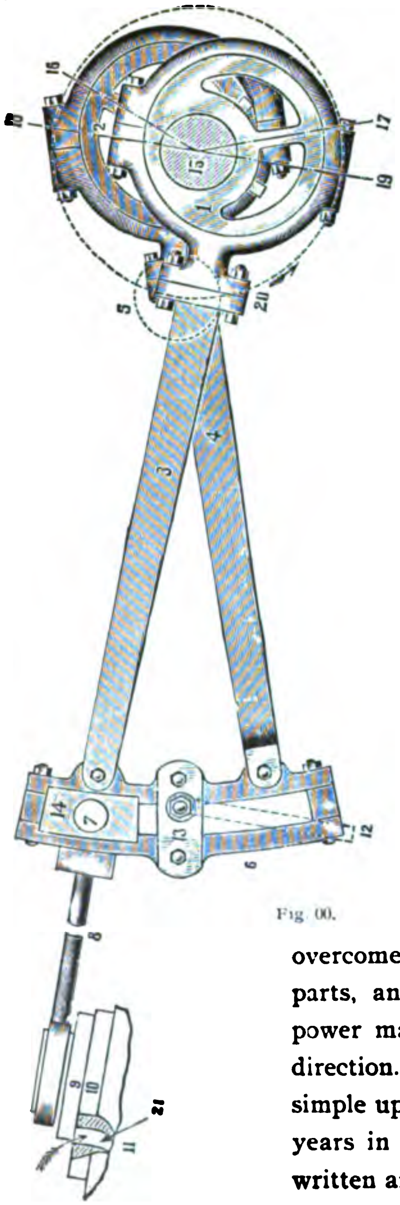

Fig. 00.

Many classes of engines, more especially those which are self-propelling or employed for hoisting purposes, need some means for the *reversal of the motion* in which the engine travels. This is effected by a most ingenious mechanism operating in connection with the eccentric of the engine known as the *reversing gear*, of which there are several, such as the *Allan*, the *Walschaert*, *link motion.*

There is still another known as the *shifting link motion*, otherwise called the "Stephenson." All these are mechanical devices by which *the crank rotation of an engine may be reversed* at the will of the engineer, with only the loss of time required to overcome the momentum of the moving parts, and by which a like speed and power may be developed in a reverse direction. This problem of reversal, so simple upon first thought, required many years in its solution. Much has been written and published upon the subject.

REVERSING VALVE GEAR.

An eccentric, when directly connected to the valve stem, always leads the crank in the direction of rotation ; reversal may therefore be secured by *shifting the eccentric around the crank shaft from one side of the crank to the other*, and giving it an equal advance in the opposite direction, or by the equivalent method of placing a separate eccentric either side of the crank.

This arrangement of two eccentrics and gearing forms a *link-motion*, a general type of which is shown on page 477.

The *saddle* and *saddle pin*, 13, afford attachment for the *suspension* or *lifting* links, 12, by means of which the link is raised and lowered. This is effected from the engineer's platform through the agency of levers and rocking shafts not shown in the illustration.

The *slide valve*, 9, is surrounded by a yoke formed in the *valve spindle*, 8, the latter being formed with jaws at its outer end to fit the link, 6. The *pin*, 7, passes through both jaws of the spindle, and the *link block*, 14, which latter is of case-hardened steel or phosphor bronze, and slides in the radial slot formed in the link. This block, 14, thus forms a constant attachment between the slide valve and the eccentrics.

To reverse motion, the link is lifted, until the other eccentric rod is in line with the link block ; the middle of the link or *midgear* is the neutral position, where no steam is admitted. At any intermediate position the valve has a reduced travel, caused by a compound motion due to both eccentrics, and this allows variable expansion by simply shifting the link a little in either direction.

Two eccentric sheaves, 1 and 2, are keyed upon the crank shaft, 15, on opposite sides of the crank pin, which is indicated by a dotted circle, 5. The general direction of motion is shown by arrow heads on the larger dotted circle, 20, which represents the crank pin path.

The lower eccentric, 1, leads the crank pin by 109½° in the running direction, as shown by its centre line, 17 ; it is therefore the *go ahead* or *forward* eccentric. Its companion, the *go astern* or *backward* eccentric, 2, is seen from the position of its centre line, 16, to lead the crank by 111° when the engine is revolving in the opposite direction. These angles, which constitute the *angular advance*, may be measured by reference to the line, 18-19, which makes a right angle with the crank pin on either side.

The *eccentric rods*, 3 and 4 are attached to either end of the shifting *link* or *quadrant*, 6, the forward eccentric rod being attached to its upper extremity for mechanical convenience, the gear as illustrated being in its normal or forward position.

WATER POWER INSTALLATIONS.

Water power installations are competing with steam engines, and also with gas engines in medium and smaller installations; but a water power development to be successful as a commercial enterprise must have certain possibilities. There must be, 1, a market for the power; 2, the cost of the power must be no greater and should be less than could be furnished by steam; 3, the water supply must be constant throughout the year. The problem finally resolves itself into Water versus Coal.

The total available water power of the rivers and streams of the United States has been estimated at two hundred million horse power. The extent of the development of this enormous power is beyond prediction by any one now living. The present generation will, however, witness a very great progress. The large annual rainfall, together with an enormous drainage area throughout the U. S., have made possible *the profitable development of thousands of water power plants.* The possibilities of electrical transmission of energy used in connection with electric power have transformed many a mountain stream hitherto of no commercial value into a source of profit.

The size of any proposed hydraulic power plant will depend upon the use to which it is to be put. If the power is to be applied where generated, as in the case of a mill located alongside a stream furnishing the supply, a size of wheel will be selected to furnish the power necessary for a fixed output of merchandise which may utilize but a small portion of the available energy, and no special care need be exercised as to the minimum volume of water during the dry season, provided the stream does not then become wholly dry. If the demand for power be such that all the available energy can be utilized, then a careful survey of the water shed must be made. Any drainage area having extreme low water during the dry season is certain to have periods of excessively high water following the winter months and the rainy seasons of the summer months.

In designing a water power plant it should be the aim to arrange the fore bays and penstocks which lead the water to the wheel so that the losses in these approaches may be as small as possible. The entrance from the head race into the fore bay, from the fore bay into the penstock and from the penstock to the motor should be smooth and well rounded; sudden changes in cross section should be avoided, and all velocities should be low except at the motor.

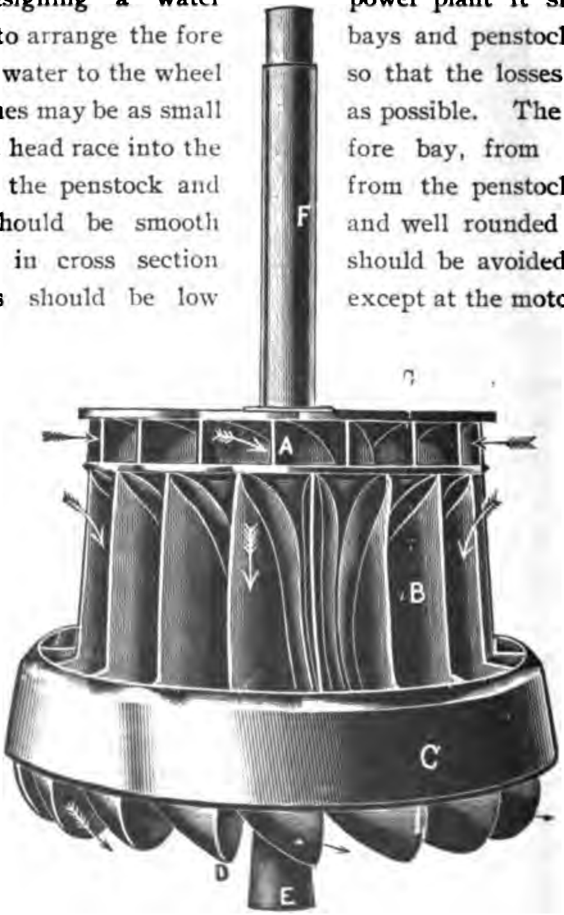

Fig. 473.—See page 481.

WATER WHEELS.

The *fore bay* mentioned in the foregoing page is that part of a mill-race where the water flows upon the wheel; the *penstock* is the conduit or trough from the source of supply to a water wheel; the *mill-race* is the current of water that drives a mill wheel, or the channel in which it flows from the dam to the fore bay; the *tail race* is the discharge pipe through which the water flows after it has done its work; a *waste channel* is a discharge opening placed on or at the origin of the head race by which surplus water escapes in time of floods.

Quite likely these definitions may be of considerable use as well as interesting to the student, especially in view of the availability of water-power for use in connection with electricity for the purposes of lighting, heating and transportation.

One of the natural prime movers is *the energy existing in falling water;* the utilization of this comes by the aid of a water wheel, upon the choice of which depends the success of nearly all hydraulic installations.

The selection of a water wheel resolves itself practically into the choice between a turbine, if for low or medium heads, and an impulse wheel for high heads; the turbine is most largely used; it is a horizontal water wheel, partial views of which are seen in Figs. 473 and 474.

Turbines receive and discharge water uniformly, and usually in each bucket simultaneously. The buckets are usually curved, and the water is guided by adjustable plates into the buckets of the revolving wheel. The delivery of water to the wheel is controlled by a series of swinging valves, which may be adjusted by hand or placed under the control of a governor. *The wheel is driven partly by the weight of the descending water* and *partly by the*

TURBINE WATER WHEEL.

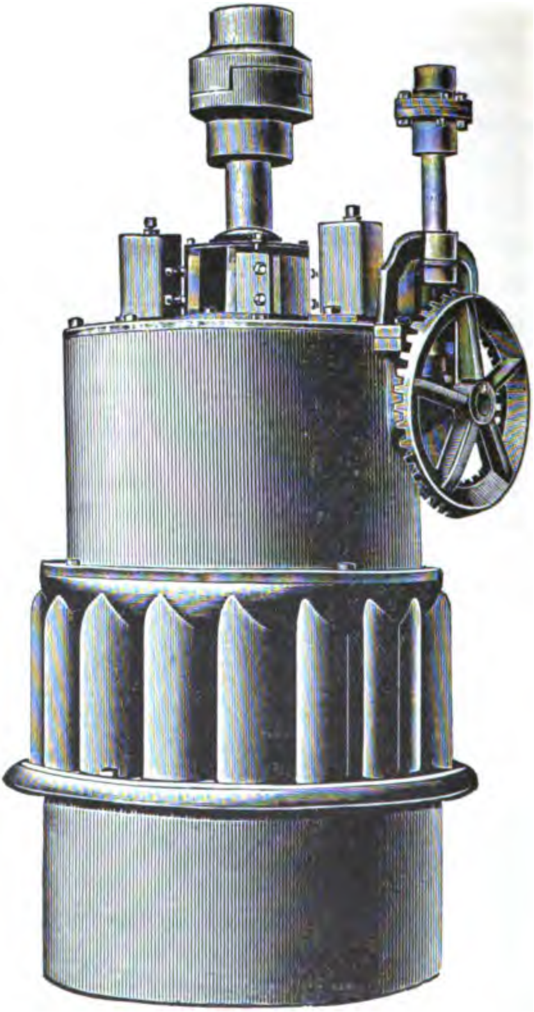

Fig. 474.—See page 481.

impulse of the flow, hence turbines may be classed as *pressure or reaction turbines*, or as *impulse turbines.*

In pressure or reaction turbines, the wheel passages are filled, the energy being largely due to pressure ; the discharge is below tail water, or in a draft tube.

Outward flow turbines receive water near the axis and deliver it outward at all points of the circumference, into buckets or curved blades of the wheel, which change the flow to a radial direction, the water leaving with little absolute tangential velocity. When the supply of water is insufficient for full power, the openings in the central chamber are partially closed by a cylindrical valve which is lowered as may be required, reducing the efficiency of the wheel, which, at best, ranges between 70 and 80 per cent.

Inward flow turbines are surrounded by annular cases in which guide passages direct the water inward to the buckets. They have a double curve in the form of the inwardly discharging bucket, so that the discharge is *downward instead of inward;* the long double curve of the bucket retains the water until it has received a very large percentage of its initial power; according to tests, the efficiency varies from 83 to 84 per cent.

Another turbine receives its water supply at the outer rim of the wheel, the water escaping axially from the centre of the wheel into the tail race. Its energy is largely due to pressure, the outlet being either drowned or connected with a draft tube. The guide blades are pivoted and so curved that the water supply can be regulated without materially affecting the angle of the blades or other conditions. A maximum efficiency of about 75% is obtained for all openings.

THE LEFFEL-SAMPSON TURBINE.

The internal arrangement of a well-known turbine water wheel is shown in Fig. 473. The "runner" which is the revolving part, as shown in the cut, is composed of two separate and distinct types of wheels, and has two diameters, as shown. Each wheel or set of buckets receives its separate quantity of water from one of the same set of guides, but each set acts only once and independently upon the water used, hence the water does not act twice upon the combined wheel as might be supposed, as in the compound steam engine.

The upper wheel *G* receives the water as shown by the arrows at *A*, and has *a central and downward discharge*, while the lower wheel *C* receives the water as shown by the arrows at *B* and has an *inward*, *downward and outward* discharge as shown by the arrows at *D*.

The engraving, Fig. 474, shows a *Hercules turbine within the case and gate ready to set in the penstock.* The design of case will naturally lead the reader to conclude that this wheel has, 1, an inward, 2, downward and, 3, an outward discharge which is correct. *The gate is simply a curb* or hollow cylinder which forms a sleeve outside the case and is raised and lowered by the gearing and rack shown in the engraving. As this sleeve rises it gradually uncovers the openings shown, which admit water into the wheel.

NOTE.—From the construction of gates and guides upon turbine wheels one may readily see the absolute necessity of carefully guarding the flume against the admission of sticks and other solid materials that might wreck the wheel or jam the gates so that they could not be operated; this is best accomplished by placing a water rack in front of the head gate at the entrance of the flume. These water racks are best made of flat bars of wrought iron placed edgewise in a vertical position, or what is better, let the top incline say one foot or two (depending upon the size of flume) towards the head gates.

WHEEL PIT AND TAIL RACE.

In practice there is almost always a loss of head due to the velocity with which the water passes through the channels leading to and away from the wheel, and it should be the aim in constructing flumes to bring the loss to a minimum. When the *size of the wheel and the quantity of water* to be used have been determined, then 1, the size of the conduit for carrying the water to the wheel, 2, the width and depth of the wheel pit and tail race, and 3, the dimensions and location of the flume for the wheel, are all to be considered and properly arranged.

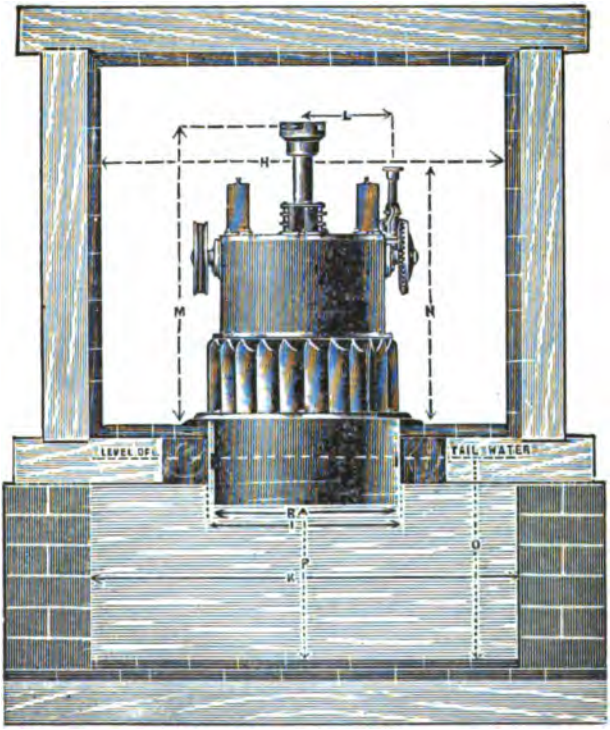

Fig. 475.—See page 464.

SUPPLY CHANNEL.

All of these should be of such dimensions as to insure the flow of water through them at a moderate velocity, and with as little change of direction as may be practicable.

The larger the pipe or canal the better, but there must be a limit in practice, and it may be laid down as a general rule that a velocity of *three feet per second* is good practice in short tubes of uniform section of not more than fifty feet in length; but *the velocity should be reduced as the distance increases*, until in a length of 200 feet, it should not exceed two feet per second.

The same rule applies to *the tail race*, except that the velocity should be somewhat lower in ditches cut through rock or earth and having the naturally resulting roughness of sides and bottom.

The width and depth of *the pit* below the wheel may, for a given wheel, vary somewhat as the water discharged into it is greater or less; therefore, the dimensions should increase with a greater head for the same wheel.

The following is an approximate rule for the dimensions of the pit, say, for a head of twenty feet: *width of pit equal to four times the diameter of wheel*, depth below the level of tail water *one and a half times the diameter of wheel.* The flume for the wheel should be about three times the diameter of the wheel in its width or diameter, and if it is decked over at the top it should be high enough inside to clear the coupling on the wheel shaft.

The general arrangements required for the proper erection of turbines are well understood by competent millwrights and do not in ordinary cases present any serious difficulties.

Fig. 475 is designed to show the setting of a turbine water wheel in *a wooden penstock.*

SETTING WATER WHEEL.

In setting the wheel in the ordinary penstock it is necessary, in the first place, to have the floor exactly level, and it is generally more convenient to lay down a ring of soft wood around the hole in the floor, as it will be much easier to dress off with a plane than the plank floor. The floor should be supported by posts under the timbers around the hole, so that there will be no settling of the floor after being once made level. As the flange on which the wheel rests is turned true, the wheel will, when placed on this level floor, stand in the exact position required, *i. e.*, the shaft will be exactly vertical.

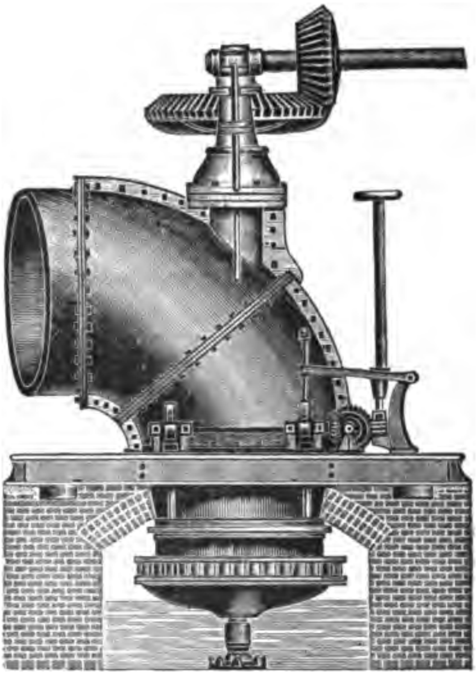

Fig 476.—See page 489.

COUNTERBALANCE CHAINS AND WEIGHTS.

If the wheel is a large one and was taken apart for shipment, the draft tube is first erected in position, then the wheel is placed on its step, the other parts being put on in their order. The step and other bearings are adjusted before leaving the shop, but it will sometimes happen that they will in some way get shifted, and as the wheel is being put together, they should be inspected and readjusted, if necessary. The only change that can occur in the step is its vertical adjustment, which is regulated by screws. When the right height is found, the broad flange around the lower part of the wheel should stand about one-sixteenth of an inch below the under side of the base of the guide rim where it rests upon the draft tube. The adjustable bearing on the top of the cover plate should be fitted up closely around the shaft, but not screwed so tightly as to bind it.

All these wheels above fifteen inches in diameter are provided with chains and weights to counterbalance the weight of the gate, so that it will move easily. It is best, when it can be done without much trouble, to carry the weights outside of the flume, but they can be used inside where the height is sufficient, although it will require a little more weight to be as effective. When the wheel is not likely to be started up at once, it is a good plan, when putting it together, to smear the step and the shaft at the bearing with tallow, as a protection against rust while it remains idle.

It is sometimes necessary to use a draft tube longer than is ordinarily attached to the wheel. If properly constructed and applied there will be no sensible loss of power, but it must be air tight, and when of considerable length it is better enlarged gradually toward the lower end, especially in cases where it may be necessary to carry this tube near the pit bottom.

IMPULSE WHEELS.

Fourneyron's turbine is shown in Fig. 476. This is, in its latest form, when properly constructed, the nearest perfect of the horizontal water wheels. It revolves either in the air or under water, and may be either high or low pressure. For the low-pressure wheel, the water enters the flume from the open reservoir, with free surface. For high pressure, the reservoir is boxed up and the water brought in at the side through a pipe. The first is for low and the second for high falls.

Impulse wheels are best suited to high heads, 200 feet and over. In turbines of this type the wheel passages are never filled, the energy being entirely due to the velocity of the discharged water from the nozzle directed against a series of buckets arranged at regular intervals on the periphery of a metal disc. The energy of the stream is absorbed by the buckets and transmitted to the shaft, the spent water falling from the buckets at no working velocity.

The end of the pipe leading water to the wheel is fitted with a nozzle in the end of which is a cylindrical tip of a diameter proportioned to the head of water and the power to be developed by the wheel. The power of a wheel of this type does not depend upon its diameter, but upon the head and quantity of water discharging into the buckets. The speed of the wheel for a given head is determined by its diameter, and this speed should be constant irrespective of the power to be developed.

NOTE.—An increase of power for a given speed of rotation can be had in the case of a small wheel by the addition of another set of buckets on the same disc with another nozzle; the power and also the quantity of water used can thus be doubled. A wheel of sufficient diameter may have two nozzles arranged to discharge into one set of buckets, the nozzles being so located that the spent water from the first discharge will not interfere with the second. Double buckets and twin nozzles are also used for the same end.

HORIZONTAL TURBINE.

High-speed turbines are had by reducing the diameter of the wheel. Turbines of the same diameter run at practically the same speed. The speed of rotation cannot be increased by merely changing the curve of bucket without a loss of efficiency; to overcome this loss turbines may be placed in tandem, but this is not recommended for regular service.

In mill practice, *power transmission from a turbine is usually to a horizontal shaft.* With a horizontal turbine the coupling may be directly at the end of the wheel shaft and transmission secured by an extended shaft, by belt or rope transmission from pulley, or coupling direct to a generator. Two horizontal turbines are commonly arranged on the same shaft, and connected in multiples of two, three or more pairs, each wheel commonly having its own draft tube, the water inlet being in a casing common to two wheels, the discharge being into a quarter turn elbow at each end of the horizontal casing or flume. The end thrust of the wheels is thus equalized and the pressure equally distributed throughout the flume.

In the case of a *Pelton wheel,* speed is controlled by means of a cast-iron deflecting nozzle provided with a ball-and-socket joint, permitting of its being raised or lowered, thus throwing the stream on or off the buckets. The power of the wheel is consequently increased or diminished to adapt to change of load, and a constant speed is maintained. The stream cut-off is a spherical plate fitting tightly over the end of the nozzle tip which, by varying its position, changes the discharge area of the nozzle, and thus influences the power of the wheel. The needle and deflecting nozzle is a most valuable combination. This accomplishes a two-fold object—accurate regulation and water economy without water ram.

PUMPING ENGINES.

A pumping engine strictly defined includes a pump and its motor united in one machine. This definition, however, would embrace all steam pumps, no matter how small—but "machines when they act with great power take the name, generally speaking, of engines"—hence, the term *pumping engine.*

It has become customary to apply the term to all *large reciprocating pumping machines* used for supplying cities and towns with water, draining lakes and marshes and other similar extensive work. The term can be regarded, therefore, only as an arbitrary and convenient one, finding its justification in an apparent necessity for some distinguishing title for a class of apparatus specialized in its construction with reference to the magnitude and nature of the duty to be performed.

The early history of the pumping engine is the history of the steam engine, for originally and for many years the only way in which the steam engine was utilized was for pumping water. In 1698 Capt. Thomas Savery secured letters patent for a machine for raising water by steam. It consisted of two boilers and two receivers for the steam, with valves and the needful pipes.

One of the receivers being filled with steam, its communication with the boiler was cut off and the steam condensed with cold water outside of it; into the vacuum thus formed the atmosphere forced the water from below, when the steam was again caused *to press upon the water* and drive it still higher. This engine was used for draining mines and the water was, in some instances, made to turn a water wheel.

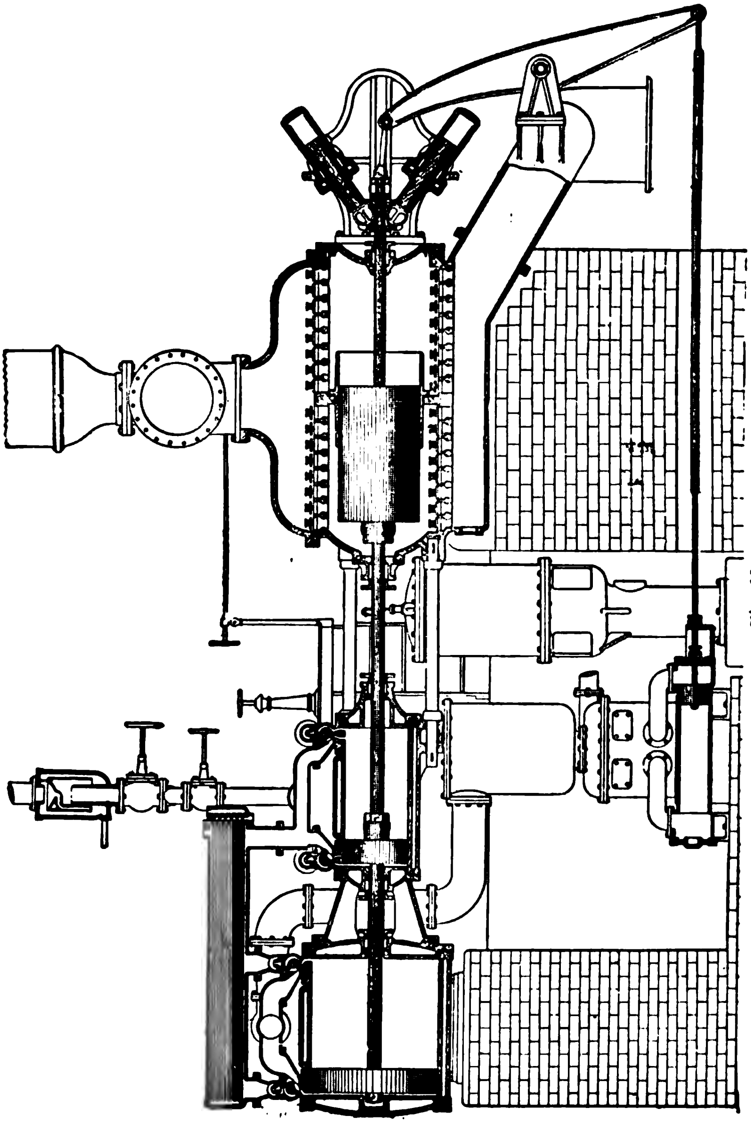

Fig 476.

PUMPING ENGINES.

In 1705 Thomas Newcomen, with his associates, patented an engine which combined, for the first time, the cylinder and piston and separate boiler. *This soon became extensively used for draining mines and collieries*, and the engines grew to be of gigantic size, with cylinders 60 inches in diameter and other parts in proportion. This engine was, in course of years, used in connection with the Cornish pump, whose performance in raising water from mines came to be a matter of the nicest scientific investigation, and adopted as the standard for *the duty or work* by which to compare many experimental machines soon afterwards introduced by other inventors.

At a more recent date Corliss first obtained a wide recognition of the merit of his engine *by guaranteeing a high rate of performance in pumping water.* The term "*duty*" *of pumps* indicates the measurement of the work done by pumps. "*Duty trials*" are careful tests of the work performed by the larger pumping engines.

A general statement of *what would be desirable in a pumping engine for most cases*, and provided there were no special reasons otherwise, would be about as follows:—

To have the *steam pistons* rigidly and directly connected to the water plungers so that no power would be transmitted through working parts and joints beyond that due to the equalization of the steam distribution.

The *steam cylinders* and the *pump cylinders* connected and supported so that the engine would be practically self-contained; and have all anchor bolts extend downward far enough into the foundations to obtain the benefit of the weight of the masonry.

The *condenser*, whether of the jet or surface type depends upon the situation, from where the condenser water is to come, *and other considerations applicable to each case by itself.* If a jet condenser is

PARTS OF PUMPING ENGINES.

used, the injection water should be taken from a point and under conditions which will insure a solid column of water containing the minimum percentage of air.

The steam cylinders and *all piping* connected with the engine, together with the receivers and all other parts where radiation of heat will represent loss, should be covered to prevent radiation, and where practicable, lagged with some suitable material.

The general construction and arrangement of the pumping engine, will of course depend upon whether it is *horizontal* or *vertical*, as either one of these types will follow lines peculiar to itself; also depending on whether the type will be rotative or non-rotative.

Bed plates where used should be proportionately deep and massive, and of design to permit the framing to be of substantial spread and strength; stationary members should, where possible, be of the box or hollow girder type, and with simple outside forms; symmetrical, appropriate and neat; exhibiting due relation to other things about the engine. *Main pillow blocks*, where used, are as a rule preferably made as a part of the bed plate, and having proper caps formed with outside lips so as to tie the pillow block shoulders firmly together. The *main pumps* constituting the water end of the machine are made in various ways and to suit the general design; but it is a good rule to follow plain forms and arrangements with pumps.

The normal action of a pump taking and discharging water is an extremely simple one, as natural as an animal breathing, and indeed almost the same sort of a performance; so that it is important to have ample *water ways* of easy and natural shapes, obstructing the flow as little as possible, and conforming to the known characteristics of water in motion.

PUMPING ENGINES.

Fig. 476 represents a *tandem compound duplex pump* of the high-duty type, as used for many water works. Two independent compound engines are placed side by side, each driving a separate pump ; the pistons of each being coupled directly to the pump rod. The valve gear on each engine is operated by levers and linkwork from the cross-head of the other ; each thus working its neighbor's valves. This is the ordinary valve gear of the duplex steam pump.

The steam passes through an efficient separator on its way from the boiler, and its admission to the high-pressure cylinder is controlled by double-ported valves of the Corliss type; the right-hand valves in both cylinders are open for steam, those on the left-hand side are both set for exhausting. This perhaps gives a clearer idea of the practical working than a lengthy description.

On its way from the high-pressure to the low-pressure cylinder the exhaust steam passes through a *reheater* containing many U tubes through which live steam is flowing—thus re-evaporating any suspended moisture. After performing its work, the steam is condensed in a *jet condenser*, whose horizontal double-acting air pump is driven from the pump tail rod through the intervention of a beam and links.

The characteristic feature of a high-duty duplex pump, the vibrating auxiliary cylinders or plungers, is shown at the right of the pump chamber. As the pump starts its stroke, these plungers are driven into their shell, compressing the air before them, the whole swinging on trunnions as the pump rod advances.

When the pump has passed its half stroke and steam is cut off by the valves, the auxiliary plunger assists to drive the rod on

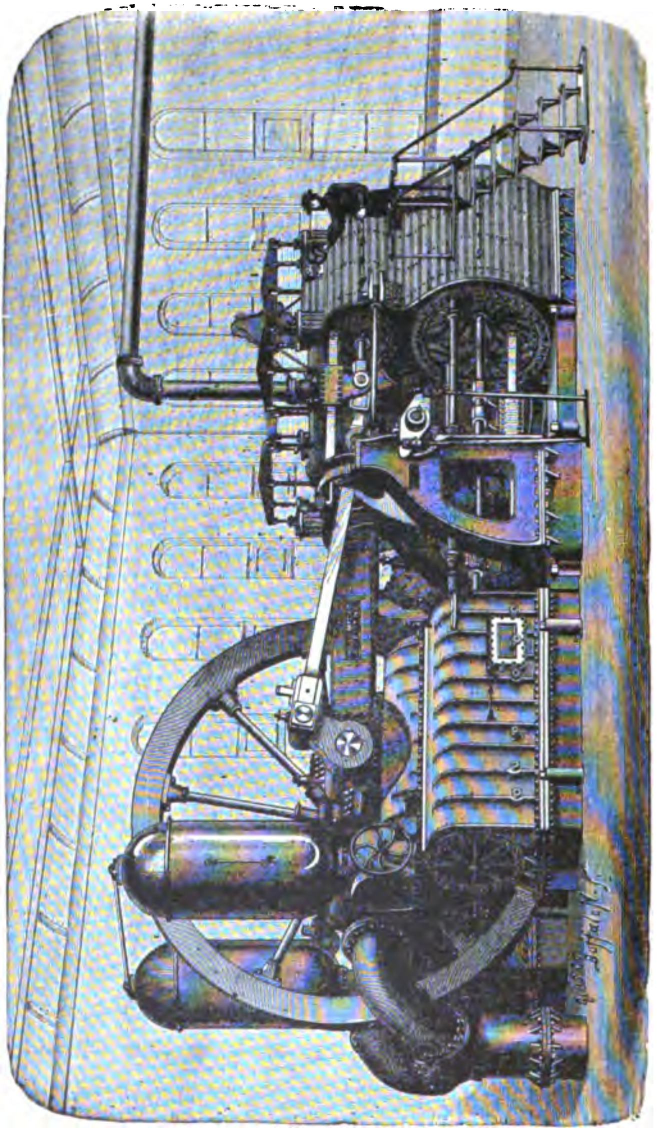

Fig. 477.

its way, thus giving up the energy stored under it at the commencement of the stroke.

Fig. 477 represents a Gaskill pumping engine made by the Holly Mfg. Co. In this design the low-pressure piston rods are directly in line with the pump plungers, the high-pressure cylinder lying on top of the low-pressure. A swinging beam and links connect the crosshead of both engines, so that power developed by the high-pressure engine which is not absorbed by driving the fly wheel is transmitted to the pump.

The high-pressure steam is controlled by double-beat valves worked by eccentrics off a cam shaft which lies at right angles to the crank shaft, being driven by bevel gearing. Flat gridiron valves between the two cylinders serve at once as exhaust valves for the high pressure and admission valves for the low pressure; separate grids being fitted for the final low-pressure exhaust. The air pump is driven off a vibrating arm on the beam gudgeon.

Fig. 478 shows a centrifugal pump of large size, the suctions being no less than 48″ bore; such a pump is a matter of necessity in a large dry dock, where it is imperative that the water be quickly emptied. Such a pump as that illustrated can remove about 16,000 tons of water per hour, to a lift of about 30 feet. It will be observed that the engines are fitted with a modification of Hackworth's valve gear.

In *selecting a site for erecting* pumping engines such as here are illustrated, great care should be used in choosing a location where the ground is firm and solid, in order that an unyielding substructure can be obtained on which to build the engine foundation. If this is not obtainable, other means must be resorted to, such as piling and capping.

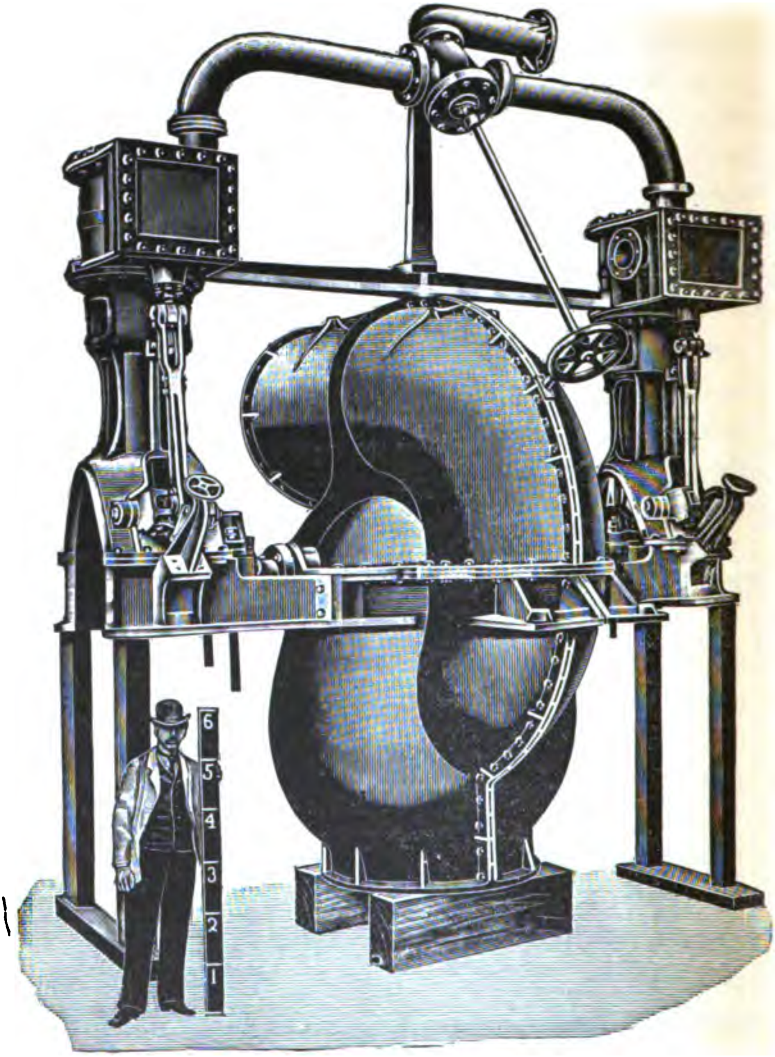

Fig. 478.

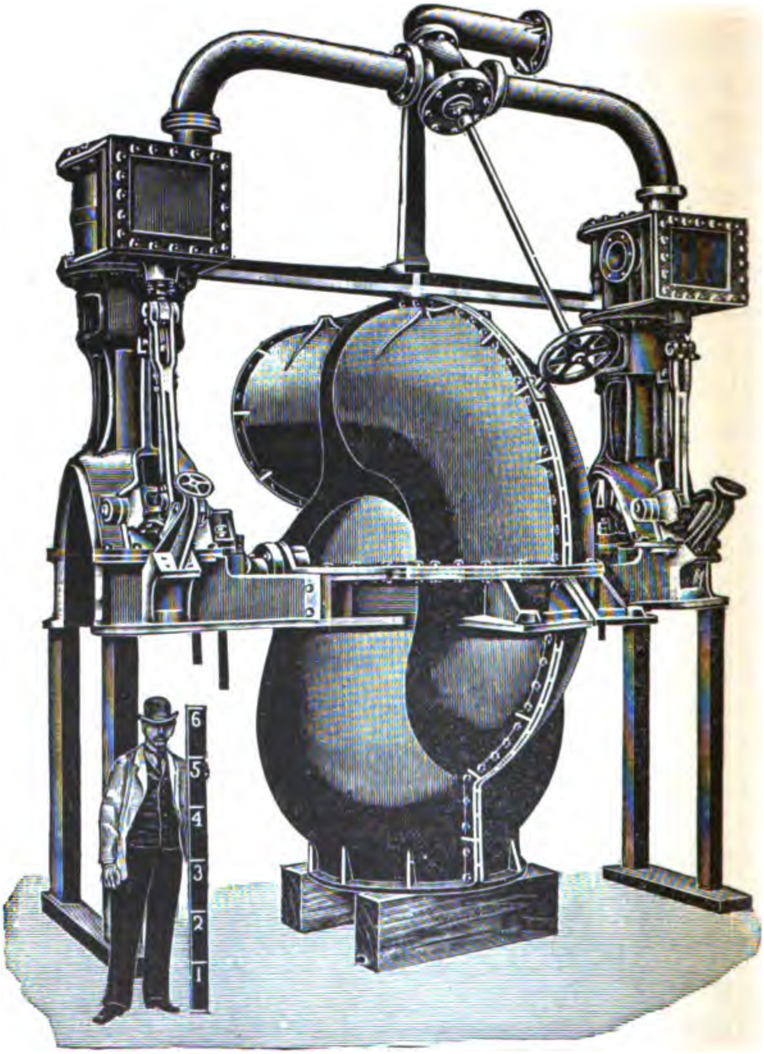

Fig. 478.

PUMPING ENGINES.

If a hard bottom cannot be reached conveniently by this means, the excavation for foundation can be made of greater size, then floored with heavy timbers securely fastened together, upon which the masonry should be built. If it is not practical to go to the estimated depth of a foundation, the same weight of masonry should be obtained by *increasing its width and length.* It is always desirable to complete the foundations at the earliest possible moment, so that the work is properly seasoned before the engine is placed in position.

A *large steam-engine pumping installation* is shown in Fig. 479; this is one of two, erected by the Water Commissioners of the City of Chicago for the purpose of water supply. The combined plants have a rated capacity of one hundred and twenty millions of gallons every twenty-four hours. The diagram is a longitudinal section of the Central Park Avenue Pumping Station, showing the arrangement of engines, boilers, etc., inside of the station. The three engines are of the standard Worthington triple-expansion "high-duty" type; each pumping engine has a capacity of 20,000,000 gallons per twenty-four hours against 150 foot head.

Each machine practically consists of two vertical tandem triple-expansion engines, independent of each other, except that one controls the steam valves of the other, one side thus always keeping just one-half stroke ahead of the other. The total height of each engine is about 60 ft. The diameters of the steam cylinders are 21 inches, 33 inches and 60 inches, and their stroke 50 inches. These cylinders are all steam-jacketed. Special care was taken in laying out the steam piping in order to allow for the expansion due to the use of super-heated steam.

WATER WORKS ENGINE.

In passing from the high to the intermediate, and the intermediate to the low-pressure cylinders, the steam passes through *receivers* in which are brass reheating pipes supplied with live steam. Full boiler pressure is carried on the high-power and intermediate-power jackets and the receivers; on the low-pressure jackets but a few pounds pressure is maintained.

Each cylinder has four valves, operated by *semi-rotative valve motion;* the feature of this motion is that there are no trips, dash-pots, or other similar arrangements, all movements being positive.

The power of the steam cylinders is transmitted directly, and in a straight line, to the *plungers* by means of side rods. The double-acting plungers are 34½ inches in diameter, and work through outside-packed stuffing-boxes in the water cylinders. The *pump valves* are of rubber, and of small diameter, there being 97 in each suction and each discharge deck.

The weight of the pistons, plungers and rods is balanced by means of a water pressure in the cylinders under the "balancing plungers." The pressure is maintained by air pumped into a closed tank connected with the balancing cylinders. A *surface condenser* is placed in the suction pipe, and all the water pumped passes through it. The *air-pump* is driven from the main engine cross-head.

Fig. 480 shows diagrammatically the disposition of the steam cylinders and the balancing plungers as described in the preceding paragraph.

The arrangement of the engine house is unusual as there is no floor other than that of the bottom of the pump pit, and a narrow gallery around the engine room a little above the street level about forty-five feet above the basement floor.

Sunk in the centre of the engine-room floor is a vertical shaft connecting with the *water-supply tunnel;* rising above the floor is an extension of this shaft built of boiler plate and lined with brick. In this extension the water rises and would stand, of course, at the same level as in the lake, were no engine taking water from the tunnel; when the station is in operation, however, this water level falls several feet.

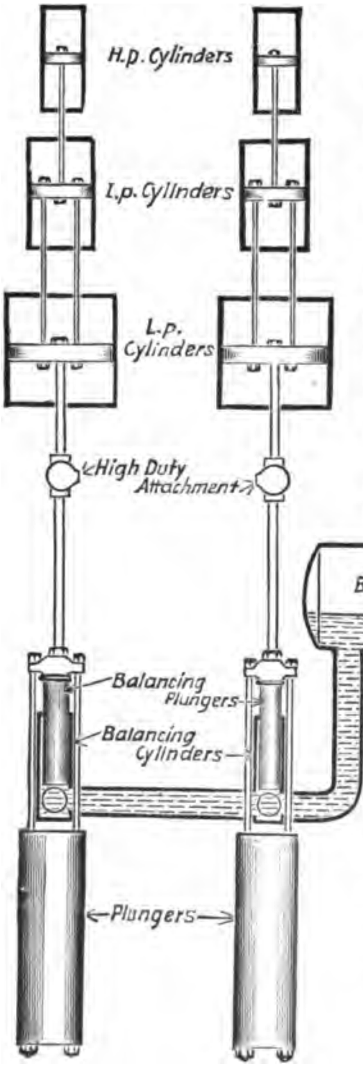

Fig. 480.

NOTE.—In order to maintain a constant water level in some of the new large docks recently constructed by the Cardiff Railway Company, it has been necessary to install a *large pumping plant*, which consists of three triple-expansion pumping engines of 900 horse-power, direct connected to three large centrifugal pumps.

Each pump is capable of delivering 100,000 gallons of water per minute against a head of 12 feet, running at 105 revolutions per minute. The main engines, of the marine type, have cylinders 19, 30 and 48 inches in diameter and a 24-inch stroke.

The cylinders are jacketed with boiler steam in the high pressure cylinders, and with steam through a reducing valve in the intermediate and low-pressure cylinders.

There are six *boilers*, rated at 225 horse-power each, of the Scotch marine type, each having two 40-inch corrugated furnaces and 140 2¼-inch tubes. Each boiler has a down-draft furnace. The water grates of these, being connected to the boilers at two points, one just below the water line and the other near the bottom, insure a good circulation in the boilers.

Coal is dumped from cars on the railroad siding into the crusher hopper. The crusher feeds the coal into an endless chain bucket conveyor which carries it up, and dumps it into any desired portion of the bunker above the boiler room. A quite unusual feature of the conveyor is that there are 90° twists in the chain of buckets, different portions of the chain thus running at right angles to each other.

The feed water for the boilers is taken from the delivery mains, and passes first through the closed heaters to the main exhaust pipes between the engines and the condensers. Then it passes to the feed pumps through an auxiliary heater in the boiler room. This heater is a standard Worthington closed heater, and into it is led the exhaust of the feed pumps and other auxiliary machinery.

In each combustion chamber is a *superheater* connected with a "header" extending along across the boilers. An outlet connection leads from each superheater into a main from which connections are made to the engines.

For these details, as well as the use of the illustration, the *Engineering News* should have credit. There are many other interesting details to be gathered by an attentive study of the diagram; especially is this true of the *foundation work* arranged for the chimney, the pumping engines and the building.

NOTES APPLICABLE TO PUMPING ENGINES.

The following notes are applicable to pumping engines of the largest capacity, such as are intended to be described in this section of the work, as well as the smallest steam-actuated boiler pumps, of which an innumerable number are in daily use:

1. *The space between the suction valve and bucket, plunger or piston*, as the case may be, should be as little as possible consistent with ample water way being given.

2. *All passages should be as straight as possible*, and when bends are necessary, the radius should be an easy one.

3. *Sudden enlargements and contractions in the passages should be avoided*, but if an alteration in the size and shape of the passage is necessary, it should be made gradually.

4. *Care should be taken that the suction pipe should be the lowest point in the pump.*

5. *If the pump is required to raise hot water*, there should be very little suction; in fact, it is best, if possible, to have the water running into the pump.

6. *Long suction pipes should always be provided with a foot-valve* just above the windbore or strainer, in the well or pit.

7. *All corners should be well rounded.*

8. *There should be as few flat surfaces as possible*, and where there are any they should be well ribbed.

9. *Joints in the suction pipes* and the suction part of the pump must be very carefully made, and perfectly tight.

10. *Change of direction in the flow of water* should be avoided as much as possible. After a current of water has received an impulse, it is necessary that the motion imparted should be continued with a uniform velocity throughout its whole course.

STEAM TURBINE.

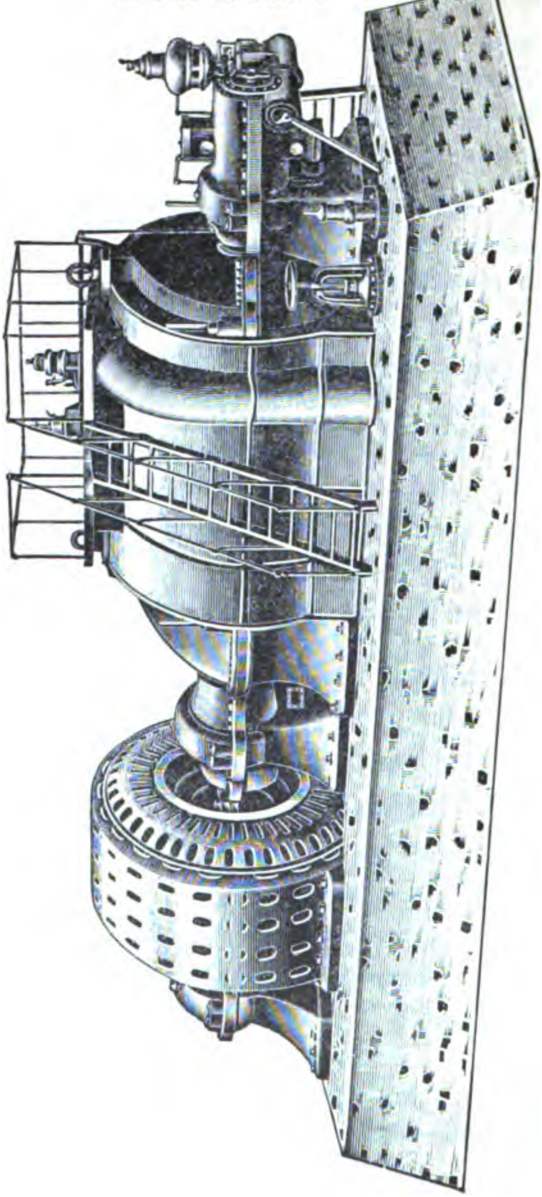

Fig. 481.—Se page 512.

THE STEAM TURBINE.

The opening of the present century was marked by no more important event in the history of industrial development than the introduction of the steam turbine for power service. The application of electricity to power work has occurred most opportunely and has furnished the greatest incentive toward the turbine's development.

One of the difficulties encountered in the introduction of the steam turbine was the entire absence of precedent, a widespread belief that the turbine had no history, that it had not been in use for a sufficient length of time to thoroughly demonstrate its merits.

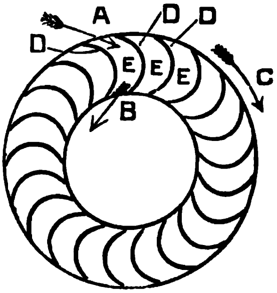

Fig. 482.

There is ample evidence that the steam turbine has established a record for economy and reliability under the most exacting service. These results may be summarized as follows:

(1.) Simplicity. (2.) Economy of steam over wide ranges of load. (3.) Mechanical efficiency because of small friction losses. (4.) Permanence of adjustment and efficiency. (5.) Ease of erection, operation and repair. (6.) Absence of wear, vibration

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NOTE.—A simple diagram—Fig. 482—presented above—shows an *elementary steam driven motor;* curved vanes D D D are set around the rim of the figure, dividing it into passages E E E; the outside arrow shows the direction of the wheel; the other arrows indicate the direction of the steam. The partitions D D D are called *vanes* or *blades* or *buckets.* The action of the steam upon the latter imparts the desired speed and direction to the wheel, which symbolizes the *rotor* of the modern steam turbine.

THE STEAM TURBINE.

and reciprocating stresses. (7.) Absence of danger from entrained water. (8.) Advantages of superheat and of high vacuum secured without increased complexity. (9.) Absolutely uniform angular velocity. (10.) Condensed steam is free from oil and may be used direct for boiler feed. (11.) Saves floor space, head room and foundations. (12.) Low cost of power-house building and equipment.

There are other advantages; turbines retain their original steam economy after years of service; the turbine has no rubbing parts but its bearings, hence a considerable saving in oil, and the exhaust steam can be used immediately for feed water. To secure the full advantages of the turbine, it requires a fairly constant load, nearly equal to its nominal capacity.

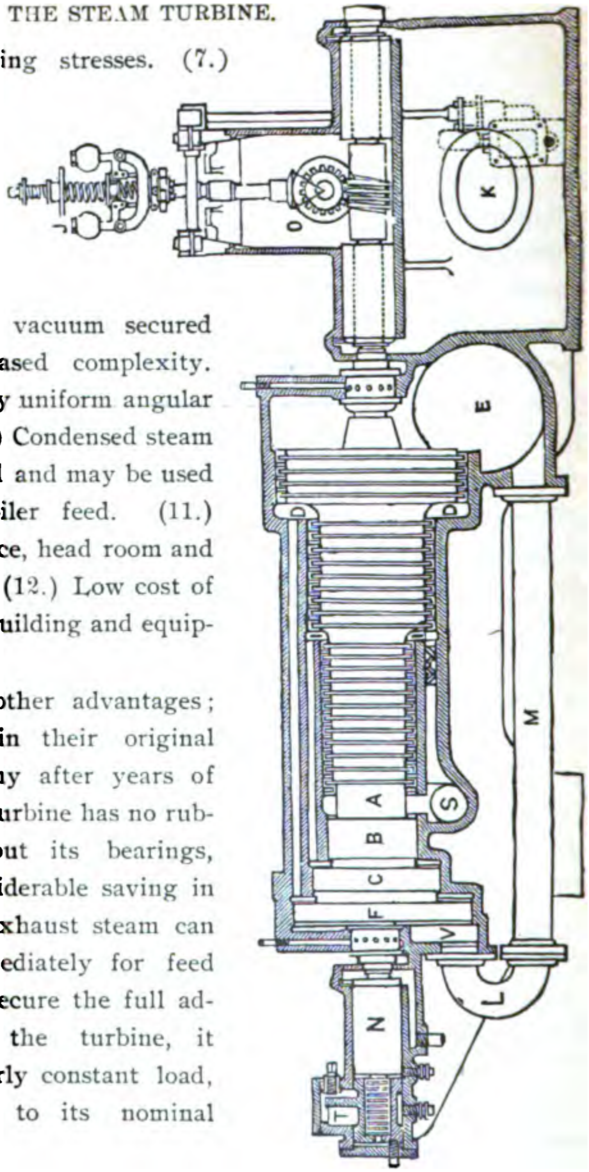


Fig. 488.

CONVEX AND CONCAVE SHROUDS.

No special type of boiler requires to be used with turbines, both shell and water-tube of ordinary construction being employed.

Certain names applied to the parts of the steam turbine have been borrowed from electrical engineering. Thus the revolving portion is known as the *rotor*, and the fixed part or the body surrounding it as the *stator*. The thousands of small blades or vanes used are known by the workmen as *keys* when they are separate from the rotor or stator. They are known as *blades* when machined out of the solid.

The blades are made of composition which is mostly bronze or what is known as Muntz metal. The "keys" are stamped out of sheet metal; many ways have been devised for securing them in position.

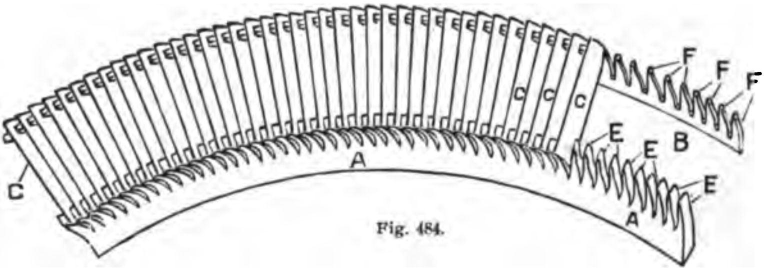


Fig. 484.

A *shroud* in the steam turbine is the device which holds the numerous small blades in their proper relative positions to each other, at the same time securing them either to the rotor or stator as may be, as shown in Fig. 484.

The shrouds are made in suitable lengths for the circumference on which they fit, and are usually made of a soft brass or a composition which may be bent. Sometimes they are made in straight lengths, the blades keyed in place, and then the whole shroud is bent to the required radius by means of a hydraulic press, either concave or convex as desired.

ROTORS AND STATORS.

The relative positions of the two series of vanes is shown in diagram form in Fig. 485, both types of blades being of uniform construction, fixed alternately as moving blades in *convex shrouds* upon the rotor, and in *concave shrouds* as fixed blades in the stator.

The steam acts upon the vanes of the steam turbine as the water does on those of the ordinary turbine, as explained on pages 481-3. The function of the fixed blades is that of the *guide-vanes* of the water turbine, namely, to direct the flow of the fluid so that it impinges upon the rotating vanes in the most effective manner.

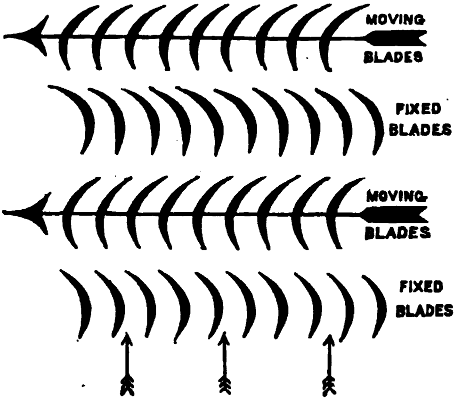


Fig. 485.

As in water turbines, the types of steam turbines may be classified according to the manner in which the motive fluid traverses them; thus there are *radial flow*, in which the steam enters near the centre and escapes towards the circumference, and *parallel flow*, in which the steam travels axially, or parallel to the length of the turning body. For purposes of illustration, an example of the latter type, the Parsons-Westinghouse is chosen.

Taking a machine of the type illustrated in perspective in Fig. 481 and in section in Fig. 483, the steam passes into a receiver at a pressure of 150 lbs. through the stop valve. In this receiver are the governor-controlled admission valves, which are actuated by a centrifugal governor, shown in the section, and shrouded by a casing in the perspective view.

STEAM TURBINE GOVERNOR.

Steam does not enter the turbine in a continuous blast, but intermittently, or in puffs. The speed regulation is therefore accomplished by proportioning the duration of these puffs to the load of the engine, this being effected by the governor, Fig. 486. The governor of the turbine has only to move a small pilot valve, or slide, E, which admits steam under the piston F, and lifts the throttle valve proper off its seat. As soon as the pilot valve closes, the spring shuts the main throttle valve.

Thus, at light loads, the main throttle or admission valve is continually opening and shutting at uniform intervals, the length of time during which it remains open depending upon the load. This is similar to the governing of gas engines, in which the speed is maintained at small loads by missing an explosion. As the load increases, the duration of the valve opening also increases, until at full load the valve does not reach its seat at all, and the steam flows steadily through the turbine.

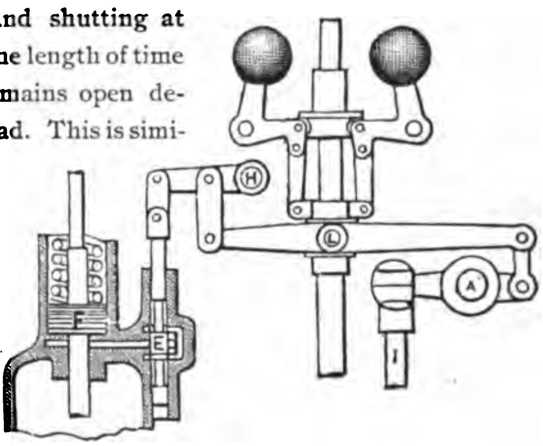


Fig. 486.

The steam thus admitted flows into the annular passage A (Fig. 483) by the opening S, and then past the blades, revolving the rotor.

When the load increases above the normal rated amount, a secondary pilot valve is moved by the same means, this in turn admitting steam to a piston, similar to F, which lifts another throttle valve. This admits steam into the annular space I in Fig. 483, so that it acts upon the larger diameter of the drum or rotor, giving largely increased power for the time being.

The levers or arms of the governor are mounted upon knife edges instead of pins, making it extremely sensitive. The tension spring may be adjusted by hand while the turbine is running.

The governor does not actually move the pilot valve, but shifts the point L in Fig. 486. A reciprocating motion is given to the rod I by a small eccentric on the governor shaft; this is driven by worm gearing shown near O in Fig. 483, so that the eccentric makes one revolution to about eight of the turbine. Thus, with a turbine running 1,200 revolutions, the rod I would be moved up and down 150 times per minute. As the points A and H are fixed, the motion is conveyed to the small pilot valve E, thus giving 150 puffs per minute. The governor in shifting the point L brings the edge of the pilot valve nearer the port and so cuts off the steam earlier.

The annular diameter or space between the rotor and the stator is gradually increased from inlet to exhaust, the blades being made longer in each ring. When the mechanical limit is reached, the diameter of the rotor is increased as at I and D so as to keep the length of blade within bounds. The turbine illustrated has three stages, but some large ones have four or more, the blades in a 2,700 horse-power set ranging from 1¾″ at the inlet to 8″ at the exhaust. This machine would have over 31,000 keys or blades, 16,000 of them being moving.

Balance pistons as at B, C, F are attached to the rotor, their office being to oppose end thrust upon those blades in corresponding diameter of the rotor. Communication is established through the passage V and pipe M between the eduction pipe and the back of these pistons, thus increasing the efficiency of their balancing and also taking care of any leakage past them.

A small thrust-bearing T prevents end play of the rotor, and is adjustable to maintain the proper clearance between the rings of blades; this varies from ⅛″ at the admission to 1″ at the exhaust. This bearing also takes up any extra unbalanced thrust.

With large steam turbines, *a high vacuum is a necessity*, as without this the turbine does not compare favorably with ordinary reciprocating engines from the point of economy. A usual method of securing the desired result is by forming a well in the lower part of the surface condenser, from which the water is drawn and delivered to the hot well by an independent pump. *Separate pumps are provided to create the vacuum*, these really being reversed air compressors, sometimes in two stages, which deal with the air alone.

Where the ordinary type of vertical air pump is employed a booster or *vacuum increaser* is added, as nothing below 26″ is admissible, 27″ or 28″ being always striven for. It is also preferable to use a certain amount of *superheat* with steam turbines, wet saturated steam placing them at a disadvantage.

To assist in producing the high vacuum, exhaust passages are made large, the eduction passage E in Fig. 483 being nearly twenty-three times the area of the steam pipe.

Among other details, a noteworthy feature is a small oil pump K, which circulates oil through bearings of the machinery, the oil being drawn from the tank under the governor shaft and gravitating there after use. No pressure of oil is employed.

Frictionless stuffing rings prevent leakage; these consist of alternate grooves and collars in shaft and bearing, like the grooves in an indicator piston.

OPERATING PRINCIPLES OF THE TURBINE.

The general principle acting upon which the steam turbine has been brought to a commercial and economic success is, that *steam expanding through a definite range of temperature and pressure exerts the same energy whether it issues from a suitable orifice or expands against a receding piston.*

Hence, keeping close to this main idea, it has been found that *the introduction of the steam turbine has modified greatly the construction of electric generating apparatus.* Where formerly of gigantic proportion to accomodate slow speed engines, the generator now is of comparatively diminutive size and of proportionately high speed. *The generator characteristics, however, necessarily determine the speed of the turbine.*

A 7500 horse-power turbine electric generator is shown on page 504; *the electrical machine is shown at one end of the illustration* and *the steam turbine at the other.* The latter has proved singularly applicable to the running of dynamos as well as to steam vessel propulsion, which afforded the first field of the motive experiments in perfecting the turbine.

Tests of the performance of steam turbines cannot be made with the indicator, but all tests are based upon either brake horse-power or electrical horse-power measurements, made in all cases with standardized instruments. The results, therefore, are not subject to the uncertainties of indicated horse-power measurements as in reciprocating engine tests.

The turbine requires no internal lubrication; its construction admits of the use of the highest superheat, and the steam may be expanded down to the lowest condenser pressure without the great increase in bulk and friction which renders the use of high vacuum ineffective in reciprocating engines.

DE LAVAL TURBINE.

With steam turbines, as with water-wheels, there are two broad classes, namely, *impulse*, and *pressure* or *reaction* turbines. In dealing with an expansive fluid, such as steam, it is difficult to make a clear distinction between the two types, as all steam wheels work partly in each manner. The Parsons turbine, previously described, is a deliberate adoption of the pressure or reaction method in order to reduce the velocity of the blades to a manageable speed, but it derives its power from both sources, namely, pressure due to reaction, and impulse due to change of velocity.

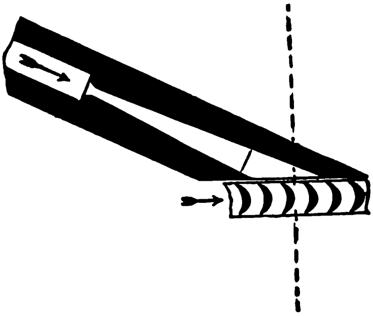


Fig. 487.

Other classes of turbines, to be presently described, are classified as impulse wheels, as the steam is permitted to attain a high velocity before entering, but as it is manifestly impossible to attain the most economical speed, namely, half the initial velocity of the steam, the impulse turbines therefore are usually made in many stages and work partly by reaction.

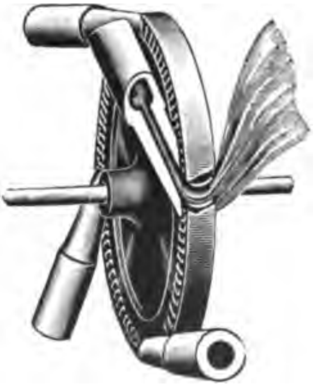


Fig. 488.

Rotary motion was first produced through HERO'S engine, by steam, about 120 B. C.; 1550 A. D. attention was called to the expansive power of steam and the vacuum which could be produced by condensation. In 1629, BRANCA designed the first steam turbine, the mechanical output of which was applied to useful purposes. In 1778, JAS. WATT patented a rotary engine in which the piston traveled around with the shaft. About 1883 DE LAVAL of Sweden, in 1884 PARSONS of England, and about 1894 CURTIS of the United States had each successfully demonstrated the possibility of economy in a non-reciprocating engine. Scores of others—even thousands—had made the same endeavor. STUMPF, SCHULTZ and SEGAR, have given their names to successful machines.

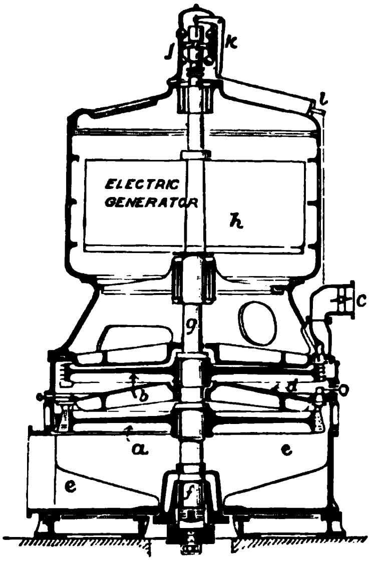


Fig. 489.

A steam turbine which acts purely by impulse or change of velocity is the *De Laval*, illustrated in Fig. 488. In this type the speed of the steam is accepted and the rotation is consequently high, the revolutions of a one hundred horse-power turbine with a twenty-inch wheel being 13000 to 14000 per minute. Double helical gearing is afterwards employed to reduce this speed to more manageable limits, there being no back lash with this type of gear.

NOTE.—In issuing through a narrow orifice only a small proportion of the heat of steam is converted into kinetic energy, or that which produces motion, but by directing the fluid through smooth and properly expanding passages nearly the whole of the pressure energy may be converted into velocity energy. The shaping and angle of these nozzles therefore constitute the most important feature of impulse turbines.

THE CURTIS TURBINE.

In this turbine, the pressure energy stored in the steam chest is converted into kinetic energy by expansion in the nozzle, shown in Fig. 487. The cone is so carefully designed that the steam is expanded down to an economical point without eddies or reactions of any sort, and is directed upon the wheel at an angle of 20°, the clearance between wheel and nozzle being about one-sixteenth of an inch. Three or four nozzles are disposed around the one wheel as shown in Fig. 488, the supply of steam being regulated by a throttling governor.

The original and daring features embodied in the De Laval turbine, combined with the utmost simplicity of construction, make it a remarkably efficient and economical machine, but its field is limited on account of the high speed. See note below.

The *Curtis turbine*, made by the General Electric Company at Schenectady, may be classified as an impulse turbine, in that it makes use of separate nozzles much like the De Laval, while the reduction of revolutions is effected by splitting the expansion up among several stages as in the Parsons.

This machine works successfully either horizontally or vertically, but for large units the vertical shaft has been deliberately chosen, and many of the advantages of the machine are due to the position.

The turbine illustrated in section in Fig. 489 has a vertical shaft *g*, driven by two wheels *a* and *b*, the revolving field magnets of the dynamo *h* being mounted on the same shaft, and the whole supported by a footstep *f*.

NOTE.—A remarkable feature of this machine is the spindle, which is made so light as to be flexible under the weight of the disc or wheel. The ends of the spindle are supported by a ball joint and floating pistons, and when in motion the shaft tends to revolve around its *centre of gravity*, thus running truly and without vibration at very great speed of rotation.

VALVES OF THE CURTIS TURBINE.

Steam enters at *c*, and flows into the steam chest; its further flow is regulated by the valves shown in the upper part of Fig. 490. These valves are raised or lowered generally through the intervention of small steam pistons, much as has been described for the Parsons turbine. The balls of the governor *j*, Fig. 489, on flying out, transmit motion through the levers *k* and *l* to a pilot valve, so that the strain on the governor is very slight.

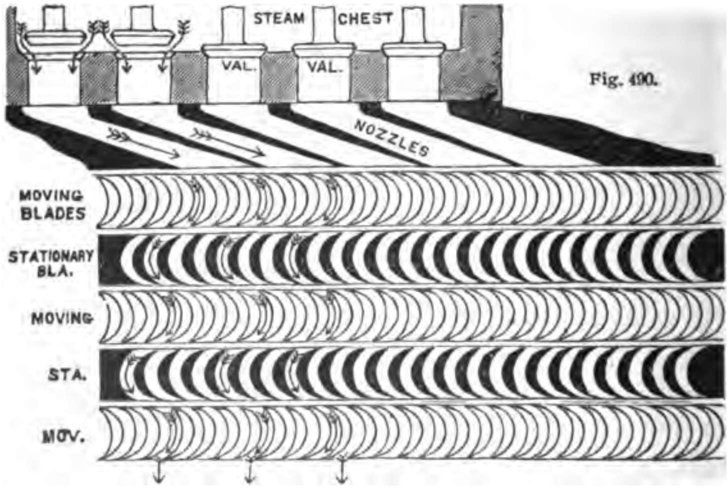


Fig. 490.

Sometimes the valves are lifted by solenoids or electro-magnets through an electric governor, at other times by mechanical means. In any event the valves open one after another in quick succession so that *a succession of puffs* follow one another around the ring.

The nozzles, shown in Fig. 490, range from four or five to twenty or more, according to size, two-thirds the number being open at full load, each of which is in connection with a sharply

GUIDE BLADES OF THE CURTIS TURBINE.

bent nozzle, much like that of the De Laval. As will be seen from the figures, there are three rings of crescent-shaped blades mounted on each wheel, with two sets of stationary guide-blades between them. These last do not extend for more than ⅙ the circumference of the turbine, that being sufficient to take care of the steam from the nozzles.

After passing through the blades of the first wheel the steam is admitted through a second series of nozzles *o*, past the diaphragm *d*, which separates the two wheel chambers. These second nozzles are the same as those shown in the figure, but have no valves or controlling apparatus. They extend about ⅕ way around the circle. The arrangement of vanes and guide blades in the lower wheel *a* is similar to that illustrated in Fig. 490, after which the steam passes into the exhaust chamber *e*, and thence to the condenser.

In practice, four wheels are usually employed, each with two to four rings of blades, the velocity of the steam being halved in each wheel, so that the speed of revolution is very moderate, while a high percentage of energy is taken from the steam. With each fresh wheel, the length of the nozzle-plate is increased until at length it occupies practically the whole circumference. The blades are made of cast steel or hard bronze, usually cut out of the solid plate, and protected at the end by a heavy shroud to which each blade is riveted.

The footstep bearing consists of two cast iron plates between which water or oil is forced at high pressure by a special pump, the pressure ranging from 400 to 900 lbs. per sq. in. Thus a skin of fluid sustains the weight of the whole machine and metal is not in contact with metal.

TURBINE FOUNDATION.

Saving in the cost of *foundations* is a claim made by the advocates of the three types of turbines heretofore described. The *Westinghouse-Parsons* has no thrust or vibration to be absorbed; any foundation strong enough to maintain alignment and to bear the weight is sufficient. This may be observed in the lower part of Fig. 481, where the power generated by the steam is utilized through the wiring system of the electrical part of the mechanism.

The simplicity of construction of the *De Laval*, the absence of reciprocating motion, and the light weight and balance of all revolving parts remove the necessity for foundations, except such as are required to sustain the weight of the larger-sized machines. In the smaller sizes no foundations are necessary, and turbines of this type of any size may be placed in the upper stories of high buildings without any preparation other than strength enough to sustain the dead load.

The foundation necessary for the *Curtis* turbine is a matter of importance only to provide a support of sufficient strength to support the weight. In many cases this is conveniently arranged with "I" beams so placed as to support the weight, leaving the space below available for auxiliary apparatus. In the case of the use of a *masonry foundation* it is customary to leave a recess in the foundation for easy access to the step.

All large turbines are necessarily dependent upon *forced lubrication.* The Curtis turbine being a vertical machine, as shown in Fig. 489, has its entire weight carried on a film of lubricating fluid. This is forced in between two cylindrical cast-iron plates bearing upon each other at the end of the vertical shaft and with a central recess to receive the lubricating fluid.

ELECTRICAL INSTALLATION.

In almost every line of applied mechanics, electricity in one form or another is now interwoven—such as, in—

1. The transmission of power by the electric motor
2. The electric railway.
3. Lighting.
4. Refining of metals.
5. Its application to the great chemical industries.
6. Telegraphy and telephony.
7. Entirely new industries.

For general purposes no motive power has proved itself quite so convenient as electricity; a volume might be written on minor applications of electricity, the subject being so vast that it can scarcely be treated here except to a limited extent. Electric heating, welding, forging, and annealing all have their place, and all are in successful operation.

Every few months some new application of electricity in minor uses comes to the front; one never knows when they may develop to a startling degree. A few of the general principles which are essential in every application of electricity to industrial purposes are given below.

The production of electricity is a transformation of energy from one form into another. *Energy is the capacity for doing work.* Usually mechanical energy is changed into electrical energy; a *dynamo* is a device for effecting the transformation.

NOTE.—Electrical engineering is the most exact in its measurements, currents as small as $\frac{1}{10,000,000}$ ampere and less, up to 2,000 or 3,000 amperes, being easily and accurately measured. The same remark applies to the measurement of electrical pressure and work.

ELECTRICAL INSTALLATION.

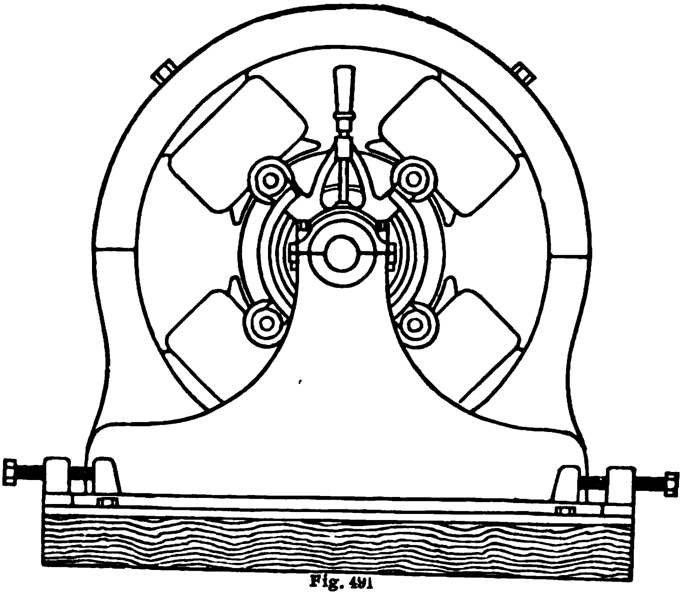


Fig. 491

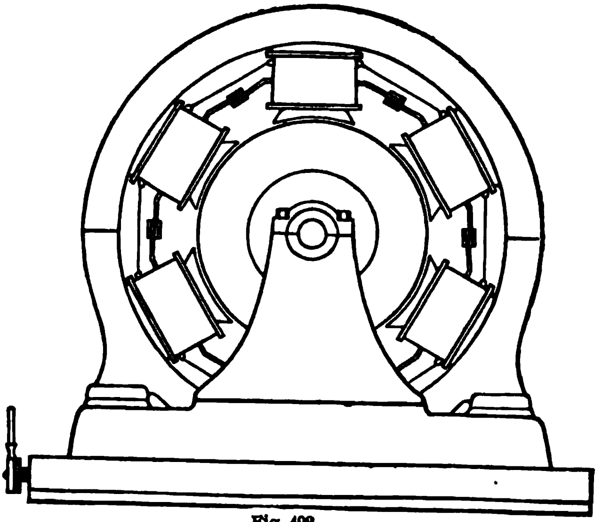


Fig. 492.

ELECTRO-MOTIVE FORCE.

It should always be remembered that electricity is something real; even if not easily defined. While it is not matter, and not energy, yet under proper conditions, it having the power of doing work, it is convenient to speak of its performance as electric energy.

Electro-motive force is a term employed to denote that which moves or tends to move electricity from one place to another; for brevity it is sometimes written E. M. F., electro-motive force. In ordinary acceptance among engineers and practical working electricians, electro-motive force is thought of as pressure, and is measured in units called volts.

Care must be taken not to confuse electro-motive force with electric force or *electric energy;* when matter is moved by a magnet, we speak rightly of magnetic force; when electricity moves matter we may speak of electric force. But E. M. F. is quite a different thing, not "force" at all, for it acts not on matter, but on electricity, and tends to move it.

The *dynamo* has been spoken of as the machine or instrument for converting electrical into mechanical energy; there are many and various forms and sizes of dynamos.

Very nearly all that can be said in relation to dynamos applies also to the *motor.* Generally speaking the dynamo is a generator of electricity, the other a motor—to transmit power through a line.

Motors are classified the same as dynamos, as *series wound, shunt wound, compound wound, bipolar* and *multipolar motors.* The motor, being intended for the distribution and application of the power generated by the dynamo, is usually a much smaller machine—thus a dynamo of 1,000 horse power will furnish the necessary force for nine or ten 100 horse-power motors.

DYNAMOS

In construction, the dynamo and motor are essentially the same, but in their action are exactly the reverse. This difference is produced by the winding of the wire used in the machine.

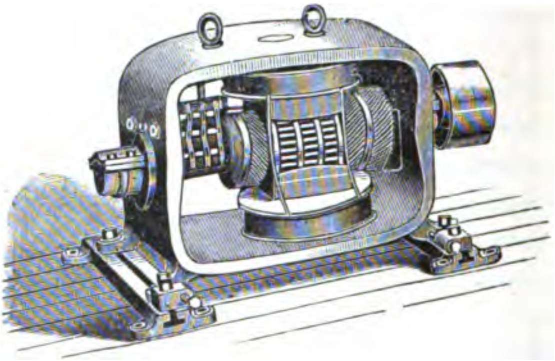


Fig. 493.

The word *dynamo*, meaning power, is one transferred from the Greek to the English language, hence the primary meaning of the term signifying the electric generator is the electric power machine. The word generator, too, is also derived from a word meaning birth-giving, hence also the dynamo is the machine gen-

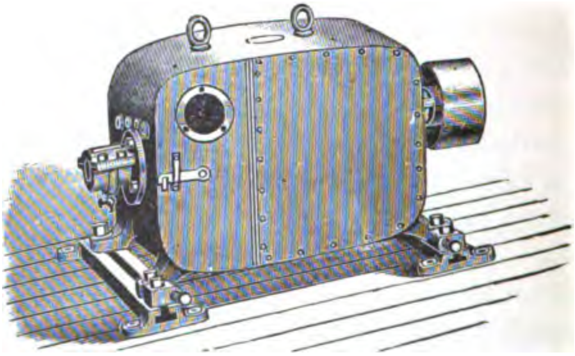


Fig. 494.

ELECTRIC MOTORS.

erating or giving birth to electricity. Again the dynamo may be described as a machine driven by power, generally steam or water, and converting the mechanical energy expended in driving it into *electrical energy of the current form.*

There is but little external difference between a motor and a generator, beyond variations in the system of wiring, the addition of a reversing switch or a resistance is all that marks the motor from the dynamo. This is due to the principle of the reversibility of the dynamo, discovered by Siemens. If a copper wire or armature is revolved at right angles to the field of an electromagnet, electricity is generated, and if electricity be supplied to the armature or coil of wire it will revolve, thus giving up mechanical energy for electrical, less a small percentage of dissipated energy.

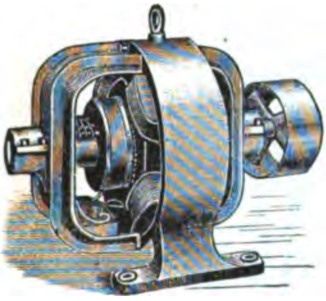


Fig 495.

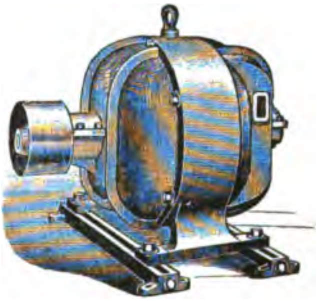


Fig. 496.

A system for the transmission of electric energy embraces: First, a conducting circuit between the two stations. Second, a battery or dynamo arranged to furnish the current. Third, the motor for changing the electric back into mechanical energy.

ELECTRICALLY-DRIVEN LATHE.

Electric transmission can be used to advantage with standard forms of machines as follows:

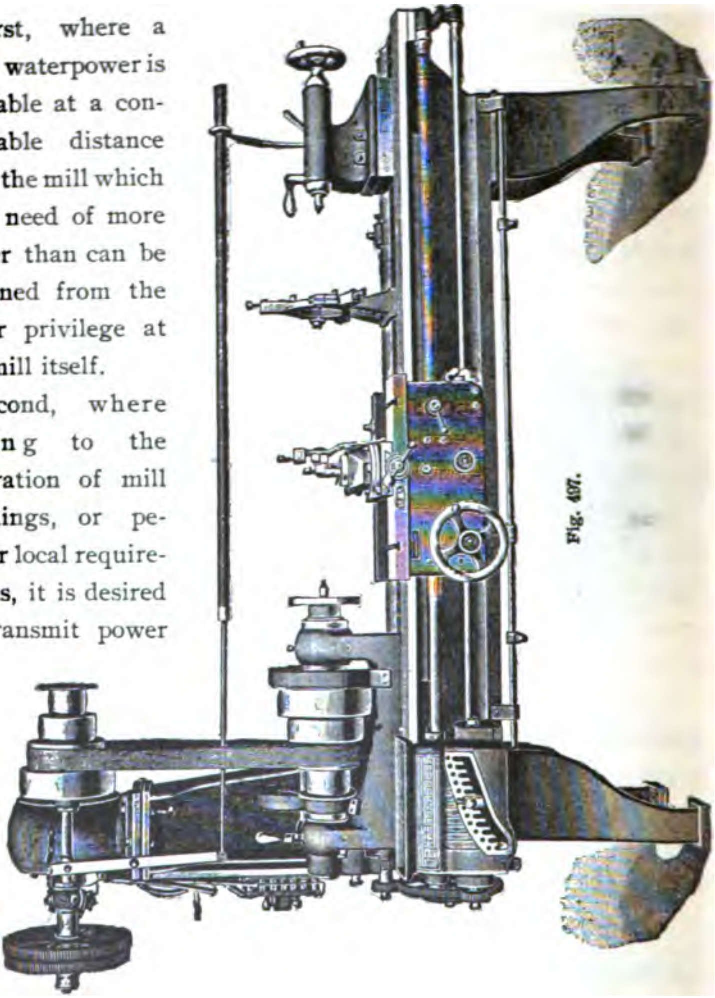


Fig. 497.

First, where a large waterpower is available at a considerable distance from the mill which is in need of more power than can be obtained from the water privilege at the mill itself.

Second, where owing to the separation of mill buildings, or peculiar local requirements, it is desired to transmit power further than can be done by belting in order to avoid the instalment of individual steam plants in each building.

ELECTRIC TRANSMISSION.

Third, where small water privileges are available at various points on a stream, but in order to become useful the power must be concentrated at one point without too great expense for maintenance and operation of the individual parts of the system.

Fourth, where for various reasons in securing a mill site it is desirable to locate at a considerable distance from the source of power on account of the fact that the land immediately adjacent to the privilege is not suitable for location.

Fifth, where for special reasons it is important to do away with shafting throughout the mill.

Fig. 491 represents the commutator end of a *four-pole machine*, so called because there are two pairs of negative and positive poles to the field magnets. The four brush arms are seen attached to the rocker. Fig. 492 is the pulley end of a six pole machine, adapted for heavy continuous currents.

It will be observed that both machines travel on cross slides. The slides in Fig. 491 are locked by set screws, abutting against lugs on the dynamo bed; the bed in Fig. 492 is adjusted by means of a screw operated by a pawl and ratchet. By these adjuncts the driving belt is kept properly tight.

A *two-pole continuous current motor* is shown in Fig. 493, its appearance as fitted for shop use being given in Fig. 494. Here it has a dust-tight case, fitted with a mica peep-hole for inspection, and porcelain bushings for the lead wires.

NOTE.—As compared to any other known method of transmitting power it may be said that electricity is an ideal agent, for as it has been well said—"Electricity never stretches, never breaks, weighs nothing, can be subdivided indefinitely with great ease, can turn corners without loss. It can transmit large amounts of energy at pressures easily controlled along wires of moderate size, and it never freezes. Its loss by friction is comparatively insignificant, and its other losses in comparison with every other known agent are almost nothing."

ELECTRICALLY-DRIVEN PLANER.

The same method of protection is given in Figs. 495 and 496, one showing the *armature* and *field magnets* of a four pole motor, and the other its appearance when closed up to exclude dust. This last type of motor is frequently provided with a reversing switch, which causes the current to flow through the armature or the field magnets in the other direction, thus producing reversal of motion of the armature. In such cases special arrangements or types of brushes are used for running in either direction.

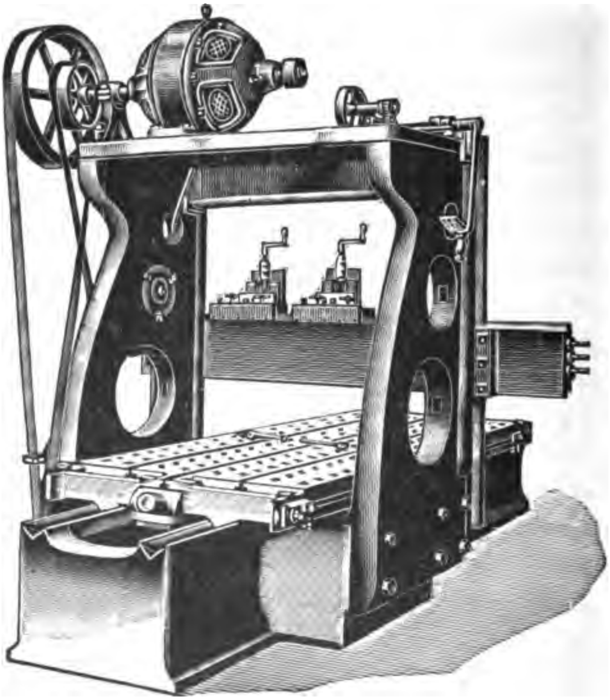


Fig. 498.

CENTRAL STATION.

Electric motors in the machine shop work so satisfactorily for power transmission, and effect such evident savings in the cost of manufacturing that they are utilized in many ways. Early ideas included the adoption of a motor for each separate machine, but present practice is to group several small machines or a small department on to one motor, using separate motors for those machines heavily or intermittently loaded, like pit lathes, cylinder boring machines or boiler yard shears.

Fig. 497 shows a method of mounting a separate motor upon a small lathe ; the motor is completely cased in, the switch being worked by the ordinary striking gear. The speed pulley is mounted upon the motor shaft, and variations in speed, to suit the load, are obtained by the use of a resistance seen on the left hand side of the column, as well as by changing the belt to different steps on the cone.

A planing machine fitted for independent electric drive, is seen in Fig. 498 ; the motor, being mounted upon the top rail of the machine, driving directly a crossed belt for the cutting stroke and an open belt for the quick return.

The electric current is generated, if practicable, at a central station where it is possible to install and operate large and economical units, thus gaining economy over small scattered steam-engines or long wasteful lines of steam-pipe. If the distances be short, a continuous or direct current is employed, led direct through mains and branches to each motor. Otherwise a high tension alternating current is employed, which is reduced down by transformers, at each separate department or building, to the normal continuous current.

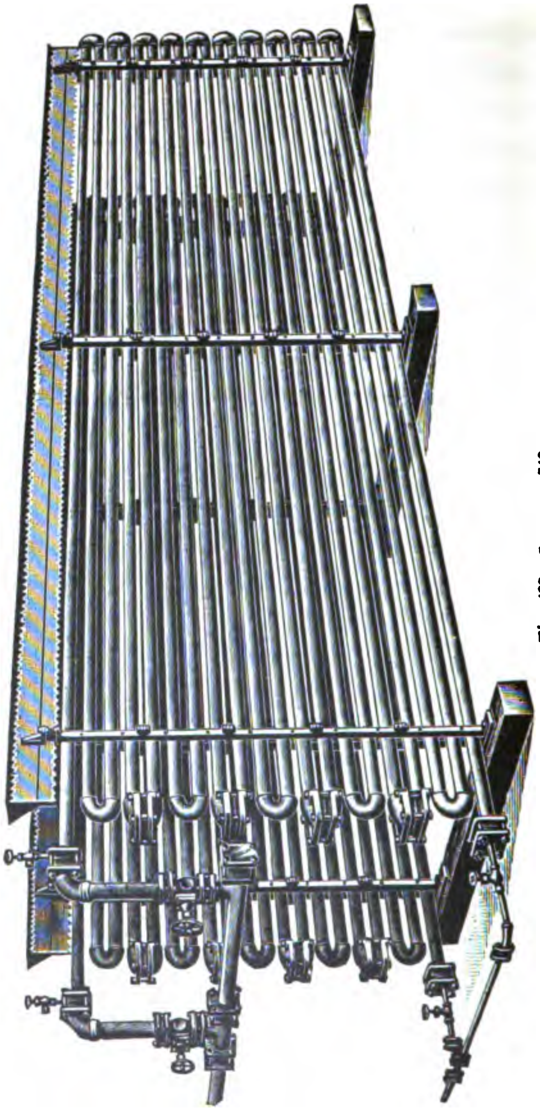


Fig. 499.—See page 540.

REFRIGERATION.

Refrigeration may be defined as the process of lowering the temperature of a body or of keeping its temperature below that of the atmosphere.

To *refrigerate*, in its primary meaning, is to make cool, anything which abates the sensation of heat; a *refrigerating machine* is an apparatus for the artificial production of cold. In such machines, mechanical power is employed for the conversion of work into heat by operating on a gas—such as air, carbonic acid or ammonia—at a temperature far removed from that at which such a gas becomes a liquid. These machines may be used for cooling air spaces or for making ice, or for both purposes, and are commonly called *ice machines*.

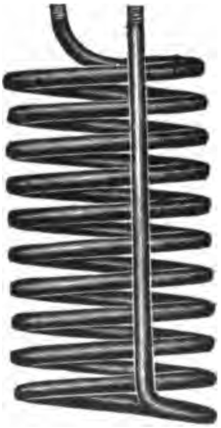


Fig. 500.

Chemical refrigeration is that produced by mixtures of substances which, by mutual solution of each other or the solution of one or more in another, become lowered in temperature by absorption of the latent heat of liquefaction from the sensible heat.

An example of a freezing mixture which has the property of producing a considerable degree of cold—that is, a sufficiently rapid absorption of heat—to freeze liquids, is found in the common case of powdered ice and salt, which may give a temperature as low as—5° Fahr.

REFRIGERATION.

Mechanical refrigeration is the conversion of work into heat by the expansion of a liquid into a gas or vapor, which produces refrigeration by reason of the latent heat of the liquid used.

In all modern refrigerating machines the abstraction of heat is brought about by the vaporization of some liquid having a low boiling point.

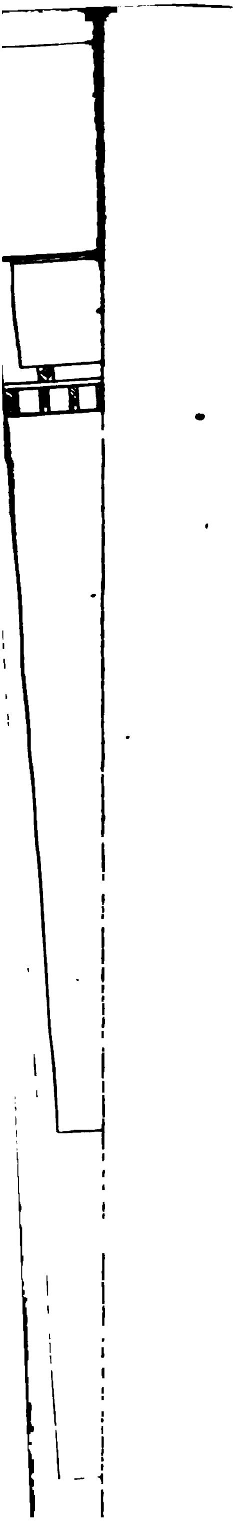
While any volatile liquid may be used, those most satisfactory from a commercial point of view are carbonic acid and anhydrous ammonia, the important requisites being that the liquid should vaporize at a low temperature under the usual atmospheric pressure, and also have a high latent heat.

The materials most largely used in refrigeration are ammonia and brine, the latter being used as an auxiliary.

Ammonia is a gaseous compound of three parts of hydrogen and one of nitrogen, with a pungent smell and taste. Water has a greater power of absorbing it than any other gas, and the aqua ammonia sold in bottles for household use is simply a weak solution in water. A much stronger solution is sold in large iron drums, weighing over 800 pounds, for manufacturing purposes. The gas itself, however, may be reduced by a pressure under 150 pounds to the square inch to a liquid form which does not contain any water, hence its name *anhydrous ammonia*, and it is in this shape that it is generally used in refrigerating machinery.

Brine is water saturated or strongly impregnated with salt. The object of using brine in refrigerating plants is to obtain a liquid which will carry a temperature lower than 32° Fahr. without freezing.

NOTE.—Carbonic acid vaporizes at—112° Fahr. and anhydrous ammonia at—29° Fahr. Now when these chemicals—visible in a liquid state—rise above these temperatures, they become invisible gases.



THREE SYSTEMS OF COOLING.

Both chloride of sodium (*common salt*) and chloride of calcium are used for this purpose, and both answer equally well within ordinary ranges of temperature.

The former, however, is apt to deposit salt and clog the pipes, so that chloride of calcium brine is largely used although its cost is greater.

There are three systems of refrigeration :

1. The *direct expansion*,
2. The *brine circulating*, and
3. The *air circulating*.

In deciding which of the above systems to use the purchaser must be governed by the conditions of his particular case. A system found efficient and economical in one industry may not be best in another. Or, sometimes, as in cold storage plants, all these systems are used, the refrigeration being furnished by a single machine.

In the *direct expansion* system the liquid ammonia is allowed to expand in pipes placed in the rooms to be cooled, and the process of expansion absorbs the heat in the surrounding atmosphere.

In the *brine circulating* system, instead of the pipes being placed directly in the rooms to be cooled, the expansion coils are placed in an insulated tank of brine. The expansion lowers the temperature of the brine, which remains in a liquid form at temperatures far below the freezing point of pure water. This cold brine is then pumped through pipe coils in the rooms to be cooled, and returns to the tank to be used over and over.

The brine system possesses a marked advantage under certain conditions. For instance, where it is desired to run the compressor only a part of the day, the brine pump is kept running continually, thus circulating the cooling fluid. Also where there are many small rooms or boxes to be cooled it is difficult to control the temperatures with the small amount of piping in each room and a separate expansion valve, but with the constant circulation of the brine the temperatures are perfectly regulated.

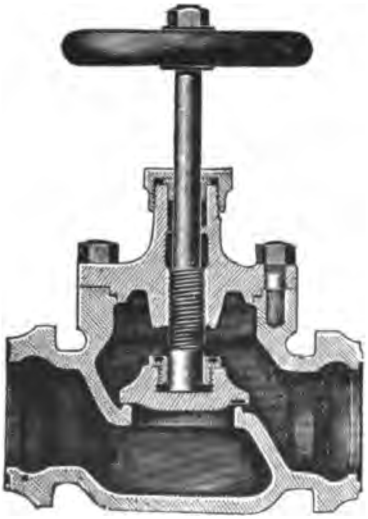


Fig. 501.

Both the direct expansion and the brine circulating systems are used in the manufacture of ice.

In the *air circulating* system the expansion coils are placed in an insulated box or room, through which the air is drawn to be cooled by passing over the coils and is then distributed to the cooling rooms, returning through ducts to the pipe room to begin the circuit again. It is not well adapted where a very low temperature is required, but an even temperature and a dry atmosphere can be successfully maintained. This system is used only in cold storage warehouses, for rooms in which furs, eggs, fruits and vegetables are stored, and for the cooling of very large rooms such as the trading room of the New York Stock Exchange.

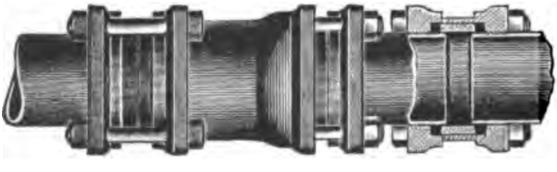


Fig. 502.

REFRIGERATING JOINTS AND VALVES.

Refrigerating capacity is measured by the cooling effect produced by the melting of one ton of ice. A ten ton refrigerating machine, when operated 24 hours daily, does the same amount of cooling that would be produced by melting 10 tons of ice.

In selecting the size of machine necessary for a plant it should be large enough to do the work when the maximum cooling is required. For this reason it is usually necessary to have a machine larger than the average consumption of ice. For cold storage purposes, or for work where the demand upon the machine is constant during the entire 24 hours, a 3 ton machine will take the place of 3 tons of ice. But if 3 tons of ice are needed in 6 hours it will require a machine four times as large, or 12 tons.

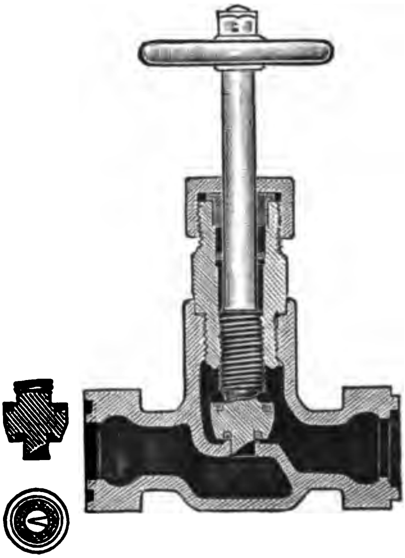


Fig. 503.

Fig. 500, page 529, is a *worm coil* similar to those used in the submerged condenser, the heat exchanger and the absorber.

Fig. 501 is an *ammonia globe valve,* and Fig. 502 represents an *expansion joint.*

NOTE.—The unit of heat used in Great Britain and the United States is called the British Thermal Unit or B. T. U. It represents the heat necessary to raise the temperature of one pound of water 1° Fahr.

The refrigerating capacity of one ton (2,000 pounds) of melting ice is 284,000 thermal units; in English practice, however, where the long ton (2,240 pounds) is used, the figures are ordinarily given as 318,080 thermal units.

REFRIGERATING JOINTS AND VALVES.

Fig. 503 is a *York ammonia expansion valve*, which is capable of very delicate adjustment. It has a soft metal seat which can be renewed.

Fig. 504 is a *reducing Boyle union*; by its use two pipes of different size can be connected with fewer joints than would ordinarily be used.

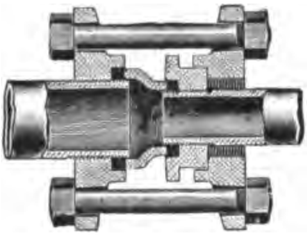


Fig. 504.

Fig. 505 shows an *ammonia tee* of standard pattern, the flanges being tapped to fit the pipe with an extra long thread; the flange is screwed on the pipe and made tight, allowing the pipe to project through the flange half an inch or so. The flanges on all fittings are made male and female, the female recess being filled with a rubber ring which fits tightly round the pipe, and when drawn together with the bolts the male side of the flange presses against the rubber ring and forces it against the threads, thus insuring a tight joint.

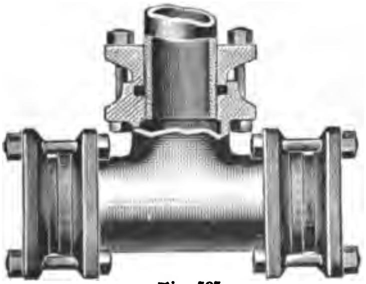


Fig. 505.

Fig. 506 represents a *Boyle union*, showing both flanges of the female type with a metal ring acting as the male part.

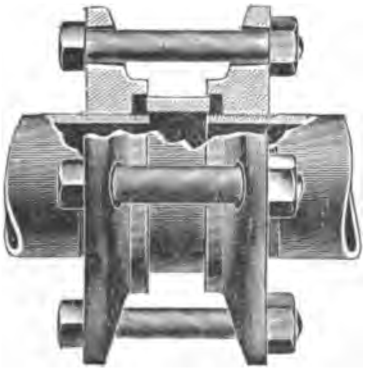


Fig. 506.

COLD AIR MACHINES.

Cold air refrigeration, as its name implies, is effected by the *compression* and *release* of ordinary air.

Under a well-known law *compression* exerted on air increases its temperature, and during its *expansion* cold is created to about the same amount.

The machines used in the air process consist of, 1, an *air compressor*, and, 2, an *expander;* the former compresses the air and passes it into a cooling coil of pipe surrounded by circulating water; this removes the heat of compression and the compressed cool air is then passed into the expander.

The *expander* or *expanding engine* of a dry-air machine consists essentially of the same principal parts as a regular cut-off steam engine: viz., cylinder, piston and slide-valve. The cold compressed air from the cooler is admitted during a portion of the stroke of the piston, its supply being regulated by the slide-valve, and the air in the cylinder is expanded as the piston proceeds to finish its stroke. On what corresponds to the exhaust stroke, the expanded air is next forced through the conveying and refrigerating pipes to the cold room, where it remains inside of pipes and does its refrigerating. These processes of *compression*, *cooling* and *expansion* are continually repeated—the same air circulating through the plant over and over again.

This type of machine requires considerable room, which cannot be well spared on shipboard, and the moisture in the air, when its temperature is reduced, becomes snow and ice and makes more or less trouble by clogging valves, etc.

NOTE.—About the first use of cold-air machines was in bringing frozen beef and mutton from Australia and New Zealand to Great Britain, and in fact that great industry owes its start to that type of machine. Cold air machines did not prove economical to operate, and before long they were supplanted by carbonic acid and ammonia machines.

CARBON DIOXIDE MACHINES.

Carbonic acid machines may be considered as following the air machines in order of use, and as having displaced them for practical work.

Carbonic acid is a gaseous compound of carbon and oxygen, colorless and without smell; it may be reduced to a liquid by high pressure and cold; it has a pleasant, pungent taste, and aerated beverages of all kinds, like soda water, etc., owe their refreshing qualities, in part, to its presence.

In the machines in which carbonic acid is used, the cycle of operation is as follows: first, a compression of the gas in a powerful pump, called a compressor, which raises its temperature; second, the hot gas then passes into coils of pipe over which cold water is allowed to run, thus carrying away the heat and liquefying the gas; then the latter passes to the refrigerating rooms and through an expansion valve which allows it to expand in the refrigerating coils and take up the heat of the surrounding atmosphere. It now returns to the compressor and the cycle is complete.

As compared with ammonia, which is much more extensively used for refrigerating purposes, carbonic acid is cheaper; it is non-corrosive; non-explosive; not dangerous to life, nor harmful to food products.

It has also no affinity for copper, hence that metal may be used for condensers when sea water only can be had for cooling.

NOTE.—While this type of machine is frequently met with in many other marine installations beside strictly cold storage steamers, its use in the United States is restricted to small machines such as those found in hotels, restaurants, etc., the very high pressure which must be carried not making them a favorite in very large plants. They also possess the advantage for marine use that they are quite compact.

AMMONIA MACHINES.

In the *ammonia absorption system* the pressure of the ammonia which results in its liquefaction is accomplished by *the direct action of heat, instead of mechanical power* as in the compression machine; the only working part being a comparatively small ammonia pump.

As the ammonia vapor returns to the plant, under low pressure, after having expanded and performed its work in the refrigerating coils, it enters a large vertical cylinder called the *absorber* which is partly filled with weak aqua ammonia.

The theory is that as water has a very great absorbing power for ammonia it will take up the returning ammonia vapor until it becomes strong or rich liquor.

As this power of absorption is greater in proportion to the coldness of the water or weak aqua, its temperature is kept down as much as possible by means of a *worm coil*, shown in the Fig. 507, passing from the top to the bottom of the absorber; to effect this result, a stream of cold water is kept continually passing through this coil.

When the absorber liquor is ready to pass into the *still* or *generator* the transfer is effected by the agency of an ammonia pump, whose aid is necessary because the pressure is much lower in the absorber than it is in the generator.

The *generator* is a large and very strong cylinder, sometimes placed vertically, but usually in a horizontal position, in which is

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NOTE.—The *strong* or *rich liquor* spoken of, differs from the *weak liquor* in the amount of ammonia gas which the water in the absorber has taken up. The strength of a solution of ammonia is shown by an instrument called a Beaumé hydrometer. It consists of a glass tube with a long bulb near the middle, and a round one near the end which is partly filled with mercury. The stem above the long bulb is marked with a graduated scale, and as the hydrometer is placed in a liquid the depth to which it sinks indicates on the scale the amount of ammonia that is held in solution.

a steam coil that heats the strong liquor as it is forced in from the absorber for the purpose of making the ammonia gas pass off from the water. This steam coil should always be covered with ammonia liquor for if the level of the latter falls low enough to expose the coils the heat of the steam may cause chemical changes in the ammonia and form *permanent gas.*

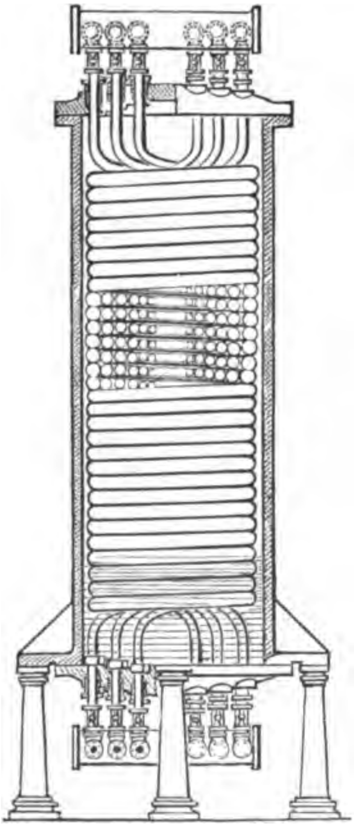


Fig. 507.

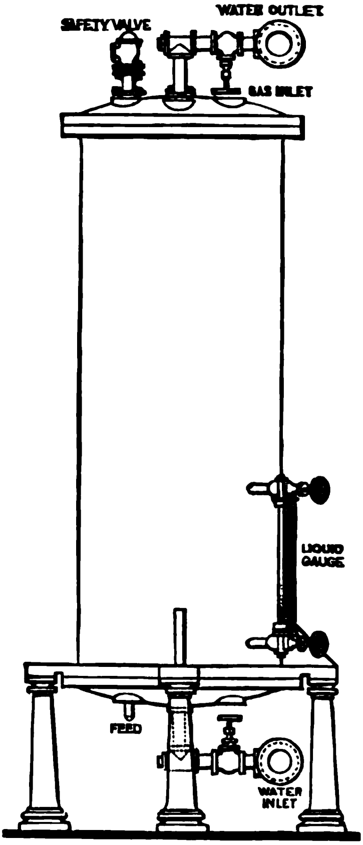


Fig. 508.

THE GENERATOR.

As the ammonia gas rises from the water it carries off some moisture, and with a view to taking it out and making *dry gas* the upper part of the generator is connected with the *analyzer*.

This is a cylinder placed vertically and having a number of shelves running out from either side, alternately. The rich liquor as it comes from the absorber enters at the top of the analyzer and pours down over these plates into the boiling liquor below.

The *analyzer* thus answers a two-fold purpose, first it raises the temperature of the absorber liquor before it falls into the generator, and second, the ammonia gas as it takes its zig-zag way between these baffle plates becomes stronger and is deprived of a considerable percentage of its moisture. The ammonia gas passes from the analyzer through the rectifier into the condenser.

The *rectifier* is a series of coils, over which cooling water is passing, very much like the condenser; its office being to condense and take out the last trace of water and leave the gas strictly *anhydrous*. This moisture is collected in a trap and flows by gravity back into the analyzer.

As the gas passes upward from the boiling liquor of the generator the solution in the lower part of the generator becomes weak, and the practice is to send it back to the absorber. It being warm, however, while it is necessary to maintain the absorber temperature as cool as possible, an ingenious device called the heat exchanger or equalizer is placed between the ammonia pump and the generator.

The *equalizer* is usually a vertical cylinder having a coil through which the weak generator liquor flows in at the top and out at the bottom, while the cold absorber liquor enters the shell at the bottom and passes out at the top on its way to the analyzer.

THE COMPRESSOR.

The effect is that *an exchange of temperature* takes place, the strong absorber liquor taking up the heat of the weak generator liquor, while the latter is reduced in temperature, and even still further lowered by being passed also through a flat cooler of horizontal pipes over which water is flowing, so that the weak generator liquor finally enters the absorber very near the temperature maintained in it.

The *ammonia pump* is a small steam pump, placed between the heat exchanger and the generator, whose duty is to draw the strong ammonia liquor from the absorber where the pressure is low and force it into the generator where the pressure is high. It is the only moving part of an absorption system and should be strong enough to run against a pressure of 500 pounds to the square inch. This pressure is considerably higher than its regular service, but is at times necessary in testing a machine, pipe line, etc., for leaks before starting up.

The type of machine used in the *ammonia compression system* produces the refrigeration by means of a powerful pump called the *compressor*, see Fig. 509, page 541. The ammonia gas under low pressure enters a valve at one end of the cylinder, and having been compressed, passes out through a second valve at the other end and goes on to the condenser, where the heat of the gas is carried away by running water. As the temperature of the gas falls, it liquefies, becoming again *anhydrous ammonia;* it now flows into the liquid receiver.

The *atmospheric condenser* is shown in Fig. 499. This consists of a series of horizontal pipes into which the warm compressed ammonia gas is forced by the action of the compressor (1) in the compression machine, or (2) the action of the heat in the steam coils of the generator in the absorption machine.

CONDENSERS.

The condensers are usually arranged in sections of four pipes each, the sections being joined by a split return bend so that they may be built up whenever desirable, or be opened for cleaning and repairs. Each stand is supplied with a stop valve on inlet and outlet, so that any stand can be shut off without interfering with the operation of the others.

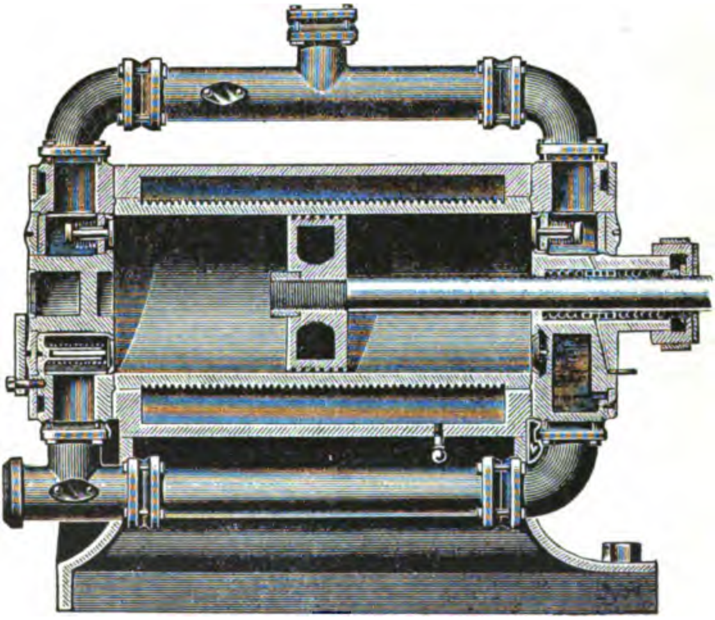


Fig. 590.

This apparatus is applicable to both the (1) compression system and (2) the absorption system.

The *cooling water* is distributed evenly at the top by means of the V-shaped trough which, as may be seen in the cut, is perforated near the top with V-shaped holes. As the water flows through these holes and down around the pipes the cooling is assisted by the evaporation of a portion of the water where the condenser is located in a current of air; the condenser is usually set in a galvanized iron pan which is connected by pipes with the drainage system.

Small-sized refrigerating plants sometimes use the *submerged condenser.* This consists of spiral coils set in a galvanized iron tank filled with water which is brought in near the bottom and flows out at the top. This type of condenser is self-contained, and no special room need be provided for it.

The *double pipe condenser* is a third form of condenser; it consists of *inner* and *outer pipes*, the *ammonia* gas flowing through the annular space between them, and the *water* through the inside pipe. The water supply is introduced at the bottom while the gas inlet is at the top. The water and gas thus travel in opposite directions through paths of considerable length. The exchange of temperature is gradual and effective, while the outside pipes radiate to the air considerable of the heat from the ammonia, resulting in a large saving of water.

The *liquid receiver* is a storage-tank used for the absorption and compression systems; it is a cylinder, commonly placed in a vertical position; its office is to receive and store the liquefied (anhydrous) ammonia as it comes over from the condenser. It should have welded heads and be capable of standing a pressure of 300 pounds or more per square inch. Its capacity should be at least half a gallon for each ton of refrigerating capacity (per 24 hours,) and it is better to have it considerably larger, for it may be necessary at times to use it for storing all the ammonia in the system while the plant is shut down or undergoing repairs.

In a small plant an ammonia cylinder may be fitted with suitable pipes and gauges and made to serve as a liquid receiver.

BRINE TANK.

Small leaks of brine from *brine tanks* may often be stopped by the use of bran, corn meal, sawdust or even sand, which should be placed in small portions at a time near the leak by means of a piece of pipe.

Whenever necessary to clean the brine *coils* the headers should be disconnected and each coil blown out by dry steam, taking care that the coils become heated thoroughly so that when the steam is shut off they will be hot enough to absorb the moisture inside. After steaming, the coils should be blown out with dry, warm air, then ammonia should be passed through each coil separately in order to drive out any remaining air.

After steaming and drying the coils, all bolts and nuts at the joints should be looked over and re-tightened, as the contraction and expansion of the pipe may have slightly loosened some of them.

The *piping* for an ammonia plant should be of extra heavy wrought iron of special quality on the high pressure side, and good wrought iron of standard weight on the low pressure side. The reason why wrought iron pipe is preferred is for the reason that it can be bent, where bends and turns are necessary, much more satisfactorily than can be done with the ordinary steel pipe, such as is generally used for gas and water service.

The *indicator* is commonly used on the compression machine to ascertain how the valves are working, but a much better method is that of placing *thermometers* on the suction and discharge lines, when the least leak on either side will show in a rising or falling temperature, while if the piston leaked on both sides the indicator would still show a good card.

The thermometer wells should be placed as near the compressor as may be practicable.

ICE TANK.

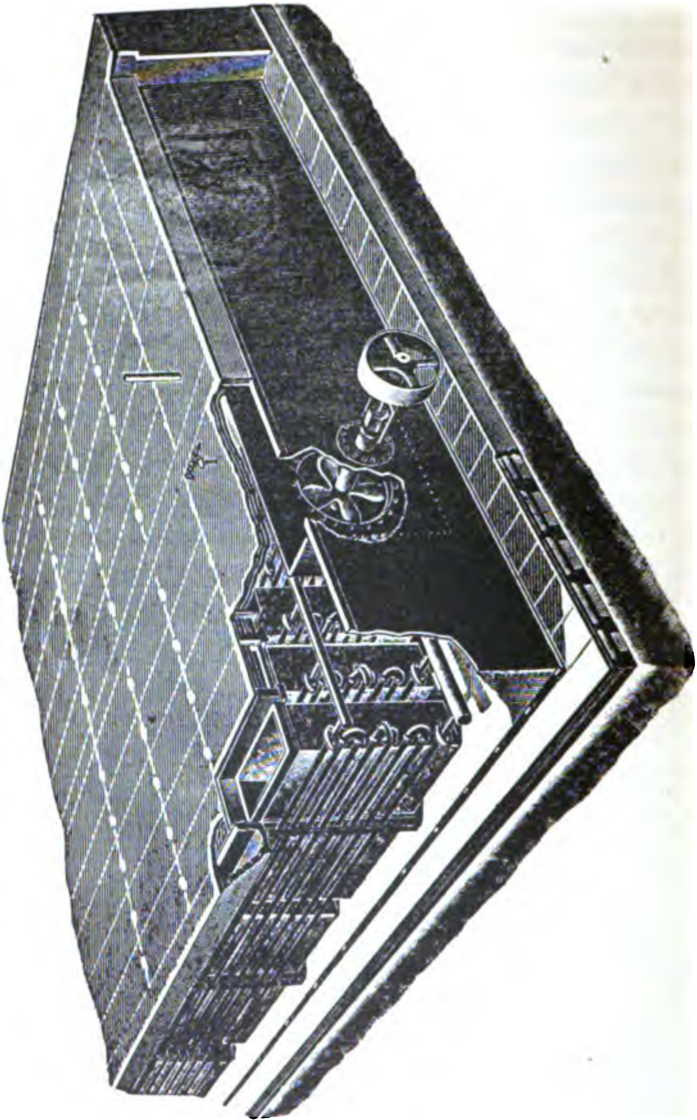


Fig. 510. - See page 545.

NATURAL AND ARTIFICIAL ICE.

Ice may be defined as water frozen or reduced to the solid state by cold. It is a white or transparent, colorless substance, crystalline and brittle; water freezes at 32° Fahr. or zero Centigrade, and ice melts at the same temperature.

Anchor ice is that which forms about stones and other objects at the bottom of running or other water and is thus attached or anchored to the ground; an *ice field* is an extensive sheet of ice; *ice house* is a close covered pit or building; *ice sludge* is bay ice broken small by the wind or waves.

Natural ice is formed from water when exposed to a low temperature, in the open air, on the surface of ponds and rivers; its principal commercial use is for keeping down the temperature of food products during the warm season to prevent their rapid deterioration. If ice is placed in the ordinary household refrigerator, when the temperature outside is above the freezing point of water, the ice slowly melts and maintains a temperature varying from 36° to 40° Fahr. in the confined and well-insulated space where the cooling effect is desired.

Artificial ice is made by refrigerating machinery in two forms, *can ice* and *plate ice*. The former is from water in galvanized iron cans which are suspended in a tank of cold brine. As the freezing is from the sides and bottom towards the middle it is difficult to prevent the entanglement of more or less air when the ice crystals form in the center, causing a white feather or core.

A form of tank used is shown in Fig. 510, page 544. The ammonia coils are placed lengthwise of the tank at intervals to allow the ice freezing cans to come down between them. An oak or ash frame-work is used to retain the can in position. A separate opening and cover is provided for each can.

The size of can for a 300-pound cake is 11″ x 22″ x 44″.

PLATE SYSTEM OF ICE MAKING.

In the *plate system* the ice tank is a deeper one, and divided up by a number of vertical detachable partitions which are made either of hollow plates through which the cold brine circulates, or of coils of pipes covered on the outside with a flat plate so as to present a smooth surface. The ice forms on this plate and freezing is continued until it is from 10 to 12 inches in thickness.

As the slab freezes only on one side it is very clear and transparent. An ordinary size is 10′ x 14′. When ready for harvesting it is detached from the iron plate by stopping the flow of cold brine and turning on warm brine which thaws off the ice. The large slab is then lifted from the tank, turned on its side, and cut into cakes of ordinary size by a circular saw.

Plate ice requires from nine to fourteen days for freezing twelve to fourteen inches in thickness. As it freezes only on one side, however, the impurities in the water are eliminated and ordinary filtered water can be used, thus avoiding the cost of distillation which is necessary with the can system.

A plate plant requires greater floor space, and the first cost is larger than in the case of a can plant, but a lower operating expense is claimed for it, and plate ice is not only clearer and of finer quality but it will also keep better than can ice if it is desirable to store it.

Ammonia cylinders are made of steel with welded heads, and contain 50 or 100 pounds of anhydrous ammonia according to size.

While they are made very strong and sufficiently large to allow for some expansion of the ammonia, great care should be taken that they are not exposed to unnecessary rise in temperature such as would be caused by leaving them in a hot boiler room or exposed to the rays of the sun.

REFRIGERATING PIPE LINES.

Without going into a discussion of the relative merits of the ammonia compression and absorption systems, it is sufficient to say here that each has its place; and local conditions will determine which type is best suited for a particular service.

For pipe line conditions where the "load" is variable, and especially if an abundant supply of cold water is obtainable from wells of moderate depth, the *absorption machine is strongly recommended* by high authorities.

The demand upon the street pipe line is subject to extreme and sudden variations, going down to the minimum at night when patrons' boxes are closed for several hours, and running up to a maximum at irregular intervals during the warm hours of the day, when many have their shops heated, and all may have boxes open for a greater or less length of time.

The general features of the street pipe line are as follows: in a conduit of vitrified earthernware about a foot in diameter, three wrought-iron pipes are laid on saddles. One of these is of extra heavy pipe, usually one and one-quarter inches in diameter, which is called the *liquid line*, as it carries the outgoing anhydrous ammonia in liquid form.

Another pipe, called the *vapor line*, varies from two to four inches in diameter. This pipe carries the ammonia in gaseous form back to the station. The third pipe is called the *vacuum line*, and is connected with the other two lines at each refrigerator, and also at manholes in the street.

Service pipes, which are branches from these street mains, smaller but otherwise similar, lead off to the premises of each customer, all three pipes being extended to the private refrigerators.

REFRIGERATING PIPE LINES.

Stop boxes, like those of a water company, are placed at the curb so that the supply may be shut off from any particular premises if necessary. The ammonia flowing through the liquid line is *under pressure* up to the wall of the refrigerator, so that no vaporization takes place, and no refrigerating work is done, in the conduits.

Just inside each refrigerator, the liquid line connects with the *expansion coil*, which is a run of piping placed in a bunker or on inner walls of the refrigerator, through an *expansion valve*, which controls the flow of ammonia from the liquid line into the expansion coil. The expansion valve is opened slightly so as to allow a very minute stream of ammonia to pass through hardly larger than a needle point. This releases the ammonia from the pressure which it has been under since leaving the central station, and as it expands and resumes its natural gaseous condition it obeys a natural law in taking up the heat which it always holds as a gas. This effect is shown almost instantly on the opening of the valve for the pipe in front of it begins to frost and before long all the pipe in the box is covered with frost so thick that no iron can be seen. At its other end, the expansion coil opens into the *vapor line*, which carries the expanded gas back to the central station and into the absorber.

There the gas is taken up by the *weak aqua* as fast as it arrives, so that in practice the pressure in the vapor line, and in the expansion coils, is kept down to very nearly atmospheric pressure. The extent of surface required in the expansion coil, and the quantity of liquid to be fed through the expansion valve, both depend upon the amount of refrigerating work to be done in the box, but the pipe service is made ample so that the ammonia needed to do the work may be vaporized within the coil.

REFRIGERATOR BOXES.

Fig. 511 shows a method of piping refrigerator boxes, which may be used for either large or small storage houses. It is intended for continuous operation either by brine or direct expansion.

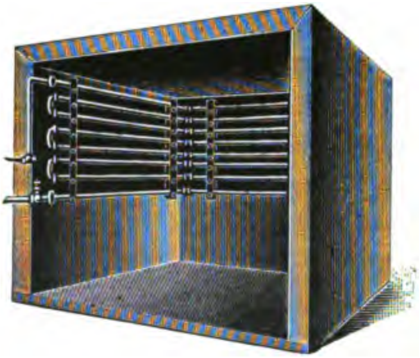


Fig. 511.

It is possible to store up a part or all of the cooling energy of the plant for use when required.

Fig. 512 shows a refrigerator box arranged to permit the machine to be operated only a part of the time and still maintain a uniform temperature in the box. The coils and tank are placed in a loft, the air circulating up a flue at the left, then across the brine tank through the coils, and down again to the room through a flue at the right. This gives a very dry atmosphere as well as low temperature. It is adapted for large meat boxes, creameries, hotel storage rooms, and small plants generally, where intermittent operation is desirable.

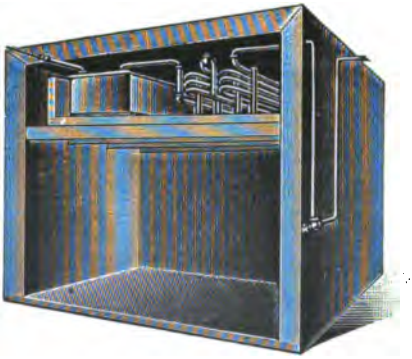


Fig. 512.

If preferred, the brine tank might be placed on a shelf, and the piping arranged beneath it, on the side of the room; or, if the goods stored are not easily damaged by moisture, the room can be piped on the ceiling.

INSULATION.

The proper insulation of refrigerator boxes and cold storage rooms is a matter of the first importance from an economical point of view, for when they have once been reduced to the desired temperature, the only work required of the refrigerating machine is what may be necessary to neutralize the heat that passes through the walls, floor and ceiling from the outside. The simplest form of insulation is a double wall of tongued and grooved boards, with several inches of space between them which is filled with some substance that is a very poor conductor of heat.

In choosing this material some other considerations beside its insulating qualities must be considered, such as its freedom from odor, its capacity for withstanding moisture, etc.

At low temperature many substances absorb moisture readily from the air, and fermentation and decay result, so that the choice of an insulating material which will withstand moisture is second in importance only to its insulating qualities. It is for this reason that granulated cork is considered one of the most desirable materials for insulating purposes.

For the proper preservation of goods in cold storage warehouses it is necessary that the air should have a proper amount of moisture and be often renewed. If the air is too dry it may cause shrinkage in some goods, or if too damp it may produce mould and decay. Generally speaking the temperature of cold storage rooms is about 34° Fahr., varying from a few degrees above for some classes of goods to several degrees below for others. Care must be taken not only to adapt the temperature to the merchandise stored, but eggs, butter, milk, cream, cheese, etc., are very liable to take up odors, and must not be put in rooms with anything that would affect them.

RULES, RECEIPTS AND COMPOSITIONS.

HOW TO ANNEAL BRASS OR COPPER.—In working brass and copper, it becomes hard, and if hammered to any great extent will split. To prevent cracking or splitting, the piece must be heated to a dull red heat and plunged into cold water; this will soften it so it can be worked easily. Be careful not to heat brass too hot, or it will fall to pieces. The piece must be annealed frequently during the process of hammering.

* * * *

BLOTTING PAPER FOR CLEANING MACHINERY.—For cleaning parts of engines and machines which are soiled by lubricating materials and dust while in use, fibrous substances, such as tow, woollen refuse, sponge cloths, jute waste, etc., are usually employed. The better varieties of cotton waste are sufficient for the clean scouring of parts of machines, but the cheaper ones are charged with dust, making the use of a sponge cloth necessary, which is specially manufactured for this purpose. Of late the use of blotting paper for scouring purposes has been recommended. The paper goes much farther than sponge cloths and woollen refuse, and as it cannot soil the machine with fibres and dust, it is decidedly preferable to cotton waste. Besides, the blotting paper is not so combustible as the other cleaning mediums. Another advantage of the paper over cotton waste is that in case it should get caught while cleaning parts of engines while in motion, it tears easily and does not draw the hand of the workman into the works.

* * * *

BELT CEMENT RECIPE.—Water, 1¼ pints; Cooper's IX Glue, 16 ozs.; white lead, dry and pulverized, 2 ozs.; alcohol 95% proof, 2 ozs. Soak the glue a while in cold water, then steam up, and when dissolved, stir in the white lead. Steam ten (10) minutes or longer, then take from over the steam and let get lukewarm. Then add the alcohol and it is made. Pour this cement out into a pan and let congeal. Then cut into small pieces and lay aside. When wanting to use, take one or more pieces and put into glue pot, adding enough water to bring to consistency of thick glue, or about 50% heavier than if for wood glue. Apply hot and quick, stirring while using as the lead settles.

* * * *

CEMENT FOR STOPPING HOLES IN CAST IRON —National Iron Filler Cement mixed with water until it is about the consistency of common paste, then it is ready for use. It should be kept in a dry place.

RULES, RECEIPTS AND COMPOSITIONS.

COMMON PEWTER.—Tin, 4 pounds ; lead, 1 pound.

* * * *

TO COLOR OR COAT ZINC.—Dissolve 1 ounce blue vitriol in 4 ounces water, add teaspoonful nitric acid. Apply with cloth.

* * * *

DRAWING THE TEMPER OF STEEL CUTTING TOOL.—The practice of blacksmiths is to continue hammering the cutting edge of the forged steel tool while it is cooling; the practice is found to close the grain and cause a close, hard, and more lasting cutting edge than if left cool without the hammering. Self-hardening steel is better—"Mushett," etc.

* * * *

TO DRILL HARD STEEL.—Use turpentine instead of oil when drilling hard steel. It will then drill readily, where oil would be of no effect.

* * * *

TO EXTRACT A SPLINTER FROM THE HAND.—Fill a wide-mouth bottle nearly full of boiling water, place the injured part over the mouth and press it slightly. The suction thus produced will draw the flesh down, and in a moment or two the steam will extract the splinter and soothe the inflammation. So says the *Technical World*.

* * * *

GLUE.—A little powdered chalk added to common glue makes it much stronger ; and a glue that will resist the action of water may be made by using skimmed milk instead of water.

* * * *

GLASS can be drilled with a triangular drill very readily, by using a mixture of turpentine and camphor. When the point of the drill has come through, it should be fed very carefully. A three-cornered file, having the edges ground sharp, makes an excellent drill. Use the corners of the file, and scraping the glass, rather than using the file as a reamer. Great care must be taken not to crack the glass or flake off parts of it in finishing the hole after the point of the drill has come through. Use the mixture freely during the drilling and scraping. The above mixture will be found very useful in drilling hard cast iron. Tempered steel can be drilled by making the drill very hard and using this mixture. A round soft copper wire with diamond dust wetted will go through glass very readily ; also used to drill porcelain. Quartz or emery may be used in place of diamond dust—preferably quartz.

RULES, RECEIPTS AND COMPOSITIONS.

GALVANIZED COATING should be *burned off*, and if the galvanized parts are to be welded, the heat for welding can be obtained at the same time. Heat the pipe or iron to a white heat and use only plain, clean sand. After preparing one end for welding, plug the opposite end so as not to burn the pipe.

* * * *

HARDENING SMALL TOOLS.—To harden small tools or articles that are likely to warp in hardening, heat very carefully, and insert in a raw potato, then draw the temper as usual. A bar of hard soap is also good, but will not make the tool as hard as the potato will.

* * * *

TO HARDEN CAST IRON.—Many times it is very convenient to make an article of cast iron that needs to be finished, and which should be very hard. Cast iron can be hardened as easily as steel, and to such a degree of hardness that a file will not touch it. Take one-half pint vitriol, one peck common salt, one-half pound saltpetre, two pounds alum, one-quarter pound prussiate potash, one-quarter pound cyanide potash; dissolve in ten gallons soft water. Be sure that all the articles are dissolved. Heat the iron to a cherry red, and quench it in the solution. If the article needs to be very hard, heat and dip the second and even the third time.

* * * *

HARD SOLDER.—Copper, 1 pound; zinc, 8 ounces.

* * * * *

IMITATION SILVER.—Copper, 4 pounds; zinc, 4 ounces.

* * * *

MOCK PLATINUM.—Copper, 4 pounds; zinc, 18 pounds.

* * * *

METAL FOR TAKING IMPRESSIONS.—Bismuth, 3 pounds; lead, 1 pound; tin, 8 ounces.

* * * *

OIL answers the same important part in machine operation that concrete does in foundations.

* * * *

PAINTING NEW IRON.—The best time for painting new iron is at the foundry as soon after casting, or being wrought or rolled, as possible. Paint it when a dry wind or warm sun will act upon it; do not paint it in the early morning or damp evening. First see that the iron is thoroughly dry and free from rust, and then coat with red lead and linseed oil, a thin coat, just enough to penetrate the pores of the iron. The first coat must dry hard. Follow up with three other coats containing red or white lead in as great proportion as possible.

* * * *

Painting Old Iron.—To paint old iron, burn off all rust and scale, brush with turpentine or paraffin and proceed precisely as with new iron.

* * * *

Plumber's Solder.—Tin, 2 pounds; lead, 5 pounds.

* * * *

Queen's Metal.—Tin, 9 pounds; antimony, 1 pound; lead, 1 pound; bismuth, 1 pound.

* * * *

Rivet Metal.—Tin, 5 pounds; zinc, 2 pounds; copper, 10 pounds.

* * * *

Rusted Screw.—To loosen a rusted screw try an application of vinegar. This will generally render its removal easy. Another plan is to heat the head of the screw by applying to it the tip of a red-hot poker. When the screw has cooled again it will be quite loose and easy to remove.

* * * *

Steel.—To harden a steel tool for a special purpose, heat it to a cherry red, drive the point into a pig or ingot of lead and leave it there until it is cold. It will prove to be hard and tough.

* * * *

To Separate Silver from Copper.—Sulphuric acid, one part; nitric acid, one part; water, one part; then boil the metal in the mixture until it dissolves; add a little salt and the silver will subside.

* * * *

Silver Colored Metal.—Tin, 50 pounds; bismuth, 1 pound; antimony, 3 pounds; copper, 3 pounds.

* * * *

To Sharpen Dull and Worn-out Files.—Lay in diluted sulphuric acid (one part acid to two parts water) over night, then rinse well in clear water; put acid in wooden vessel.

* * * *

To Soften Steel.—Heat steel to a low cherry red, and when cooled so it is black in a dark place cool in the juice or water of common beans.

RULES, RECEIPTS AND COMPOSITIONS.

Type Metal.—Lead, nine parts; antimony, two parts; bismuth, two parts.

* * * *

Tinning Acid for Brass or Copper.—Muriatic acid, 1 pound; give all the zinc it will dissolve; add 4 ounces of sal ammoniac, 1 pint water.

* * * *

For Tinning Brass.—Water, 4 gallons; salt, 1 pint; cream tartar, 1 pound.

* * * *

Vaseline rubbed into the hand morning and noon is a good protection against dirt and grease. It works into the pores of the skin and forms a coating which is impregnable. At night it should be washed off, using soft water and a good soap lather. After a thick lather is obtained the hands should be dipped into corn meal and thoroughly rubbed together before being rinsed.

* * * *

Velocity of Running Water.—The velocity of a stream can be found by laying off 100 feet on the bank and throwing a float into it at the middle, noting the time passing over the 100 feet. Do this a number of times and take the average. Then dividing this distance by the time gives the velocity in feet per minute at the surface. As the top of the stream flows faster than the bottom or sides—the difference being about 8%—it is better to measure a distance of 120 feet for float and reckon it as 100.

* * * *

White Metal.—Copper, 5 pounds; zinc, 3 pounds; lead, 1 pound; tin, 1 pound.

* * * *

Yellow Brass.—Zinc, 10 pounds; lead, 4 ounces; copper, 24 pounds.

* * * *

Yellow Solder.—Copper and zinc, equal parts.

* * * *

Zinc.—In painting zinc, the first coat should consist of white lead, red lead and turpentine, tempered with varnish. Wash new rolled sheet zinc with a solution of a tablespoonful of hydrochloric or nitric acid to a gallon of water, or scratch the surface with No. 2 glass-paper before painting.

RULES, RECEIPTS AND COMPOSITIONS.

1. A U. S. gallon of fresh water weighs 8⅓ lbs , and contains 231 cubic inches.

* * * *

2. A cubic foot of water weighs 62.3 lbs., and contains 1,728 cubic inches or 7½ gallons.

* * * *

3. A " miner's inch " of water is approximately equal to a supply of 12 gallons per minute.

* * * *

4. The friction of water in pipes increases with the square of its velocity.

* * * *

5. The discharging power of pipes increases with the square root of the fifth power of their diameters, thus doubling the diameter increases the discharged quantity 5.66 times.

* * * *

6. *To find the area of a piston*, square the diameter and multiply by .7854.

* * * *

7. In calculating horse-power of tubular boilers 15 square feet of heating surface is equivalent to one nominal horse-power. By general agreement a horse-power as applied to steam boilers is thirty (30) pounds of *feed water* at a temperature of 100 degrees Fahr. converted into steam in 1 hour at 70 pounds gauge pressure.

* * * *

8. The mean pressure of the atmosphere is usually estimated at 14.7 lbs. per square inch at sea level, so that with a perfect vacuum it will sustain a column of mercury 30 inches, or a column of water 34 feet high.

* * * *

9. *To find the capacity of a cylinder in gallons:* Multiplying the area in inches by the stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a gallon in inches) and the quotient is the capacity in gallons.

* * * *

10. *To find the pressure in pounds per square inch of a column of water*, multiply the height of the column in feet by .434. To find the head in feet, multiply the pressure by 2.31.

* * * *

11. The area of the steam piston, multiplied by the steam pressure, gives the total force exerted. The area of the water piston, multiplied by the pressure of water per square inch, gives the resistance. A margin of from 25 to 50 per cent. must be added to move the piston at the required speed, and to compensate for variations in steam pressure.

RULES, RECEIPTS AND COMPOSITIONS.

12. *To find the net pump end horse-power* exerted in pumping a given quantity of water against a given total head: Multiply U. S. gallons pumped per minute by 8⅓; multiply the product by the total head in feet, and divide by 33,000.

Thus, 100 gallons per minute against a total head of

$$100\text{ feet} = \frac{100 \times 8.33 \times 100}{33,000} = 2.52\text{ net pump end horse-power.}$$

* * * *

13. *To find the steam consumption per hour* corresponding to a given duty per 1,000 lbs. of steam: Multiply 1,980,000 by 1,000 and divide by the duty per 1,000 lbs of steam.

$$\text{Thus, } 25,000,000 \text{ duty per } 1,000 \text{ pounds of steam} = \frac{1,980,000 \times 1,000}{25,000,000} = 79.2$$

lbs. of steam per net pump end horse-power per hour.

* * * *

14. *To find the total steam consumption per hour;* capacity per minute, total head and duty per 1,000 lbs. of steam being given: Assume, as above, 100 gallons per minute against 100 feet and 25 million duty. Then 100 gallons against 100 feet=2.52 net pump end horse power; and 25 million duty=79.2 lbs. of steam per net pump end horse-power per hour. Therefore, 2.52 × 79.2=199.58 lbs. of steam per hour.

* * * *

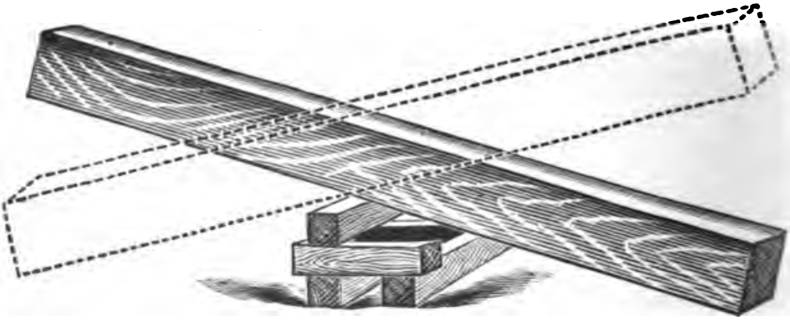
15. *To find the approximate boiler horse-power required:* Divide the total steam consumption per hour by 30.

Thus, 199.58 ÷ 30=6.65 boiler horse-power (Centennial Standard).

* * * *

16. *To find the coal consumption per hour* corresponding to a given capacity per minute, total head, duty per 1,000 lbs. of steam and evaporation per pound of coal under running conditions of feed-water temperature and steam pressure: Divide the total steam consumption per hour by the evaporation per pound of coal. Assume, as in the previous examples, 100 gallons per minute against 100 feet, 25,000,000 duty per 1,000 lbs. of steam and also an evaporation of 8 lbs. of water under running conditions, per pound of coal.

Then, 199.58÷8=24.94 lbs. of coal per hour.



TABLES

DIFFERENT STANDARDS FOR WIRE GAUGE IN USE IN THE UNITED STATES.

Dimensions of Sizes in Decimal Parts of an Inch.

Number of Wire Gauge	American or Brown & Sharpe	Birmingham or Stubs' Wire	Washburn & Moen Mfg. Co., Worcester, Mass.	Trenton Iron Co., Trenton, N. J.	Stubs' Steel Wire	U. S. Standard for Plate	Number of Wire Gauge
000000	...	...	...	...	...	.46875	000000
00000	...	...	...	.45	...	.4375	00000
0000	.46	.454	.3938	.4	...	.40625	0000
000	.40964	.425	.3625	.36	...	.375	000
00	.3648	.38	.3310	.33	...	.34375	00
0	.32486	.34	.3065	.305	...	.3125	0
1	.2893	.3	.2830	.285	.227	.28125	1
2	.25763	.284	.2625	.265	.219	.265625	2
3	.22942	.259	.2437	.245	.212	.25	3
4	.20431	.238	.2253	.225	.207	.234375	4
5	.18194	.22	.2070	.205	.204	.21875	5
6	.16202	.203	.1920	.19	.201	.203125	6
7	.14428	.18	.1770	.175	.199	.1875	7
8	.12849	.165	.1620	.16	.197	.171875	8
9	.11443	.148	.1483	.145	.194	.15625	9
10	.10189	.134	.1350	.13	.191	.140625	10
11	.090742	.12	.1205	.1175	.188	.125	11
12	.080808	.109	.1055	.105	.185	.109375	12
13	.071961	.095	.0915	.0925	.182	.09375	13
14	.064084	.083	.0800	.08	.180	.078125	14
15	.057068	.072	.0720	.07	.178	.0703125	15
16	.05082	.065	.0625	.061	.175	.0625	16
17	.045257	.058	.0540	.0525	.172	.05625	17
18	.040303	.049	.0475	.045	.168	.05	18
19	.03589	.042	.0410	.04	.164	.04375	19
20	.031961	.035	.0348	.035	.161	.0375	20
21	.028462	.032	.03175	.031	.157	.034375	21
22	.025347	.028	.0286	.028	.155	.03125	22
23	.022571	.025	.0258	.025	.153	.028125	23
24	.0201	.022	.0230	.0225	.151	.025	24
25	.0179	.02	.0204	.02	.148	.021875	25
26	.01594	.018	.0181	.018	.146	.01875	26
27	.014195	.016	.0173	.017	.143	.0171875	27
28	.012641	.014	.0162	.016	.139	.015625	28
29	.011257	.013	.0150	.015	.134	.0140625	29
30	.010025	.012	.0140	.014	.127	.0125	30
31	.008928	.01	.0132	.013	.120	.0109375	31
32	.00795	.009	.0128	.012	.115	.01015625	32
33	.00708	.008	.0118	.011	.112	.009375	33
34	.006304	.007	.0104	.01	.110	.00859375	34
35	.005614	.005	.0095	.0095	.108	.0078125	35
36	.005	.004	.0090	.009	.106	.00703125	36
37	.004453	...	...	.0085	.103	.006640625	37
38	.003965	...	...	.008	.101	.00625	38

TABLE.

BEARING POWER OF SOILS.

KIND OF MATERIAL	Bearing Power in tons per square foot	
	Min.	Max.
Rock, hard	25	30
Rock, soft	5	10
Clay, on thick beds always dry	4	6
Clay, on thick beds moderately dry.	2	4
Clay, soft	1	2
Gravel and coarse sand well cemented	8	10
Sand, compact and well cemented	4	6
Sand, clean and dry	2	4
Quicksand, alluvial soils, etc	0.5	1

TABLE.

BEARING VALUE OF PILES.

SOIL	Pile Length Feet	Average Diameter Inches	Penetration Inches	Load in Tons
Silt	40	10	6	2½
Mud	30	8	2	6
Soft earth with boulders or log	30	8	1½	7
Moderately firm earth with boulders or log	30	8	1	9
Soft earth or clay	30	10	1	9
Quicksand	30	8	½	12
Firm earth	30	8	½	12
Firm earth into sand or gravel	20	8	¼	14
Firm earth to rock	20	8	0	20
Sand	20	8	0	20
Gravel	15	8	0	20

NOTE.—This is with average penetration for last five blows of a 1,200 pound hammer falling 15 feet.

TACKS.

OUNCE.	LENGTH IN INCHES	NUMBER TO POUND
1	1/8	16,000
1½	3/16	10,650
2	1/4	8,000
2½	5/16	6,400
3	3/8	5,330
4	7/16	4,000
6	9/16	2,660
8	5/8	2,000
10	11/16	1,600
12	3/4	1,330
14	13/16	1,140
16	7/8	1,000
18	15/16	890
20	1″	800
22	1 1/16	725
24	1 1/8	665

A cut nail loses from 40 to 45% of its adhesive resistance the moment it has been slightly withdrawn.

TABLE.

FOR CONVERTING WATER-GAUGE PRESSURE INTO POUNDS PER SQUARE INCH.

Inches of Water	℔ per square inch	Inches of Water	℔ per square inch	Inches of Water	℔ per square inch
½	.0180	2	.0721	6	.2163
¾	.0270	2½	.0901	7	.2524
1	.0360	3	.1081	8	.2884
1¼	.0450	3½	.1261	9	.3245
1½	.0540	4	.1442	10	.3605
1¾	.0631	5	.1803	11	.3966

Water-gauges are used largely to determine the air pressure in connection with *blowing fans.*

TABLE.

TENSILE STRENGTH OF CEMENT MORTAR.

AGE OF MORTAR WHEN TESTED.	Average tensile strength in pounds per sq. inch			
	PORTLAND		ROSENDALE	
CLEAR CEMENT	Min.	Max.	Min.	Max.
1 day—1 hour or until set, in air, the remainder of the time in water	100	140	40	80
1 week—1 day in air, remainder of the time in water	250	550	60	100
4 weeks—1 day in air, remainder of the time in water...........	350	700	100	150
1 year—1 day in air, remainder of the time in water.............	450	800	300	400

TABLE
For Converting Feet Head into Pressure per Square Inch of Water.

Feet Head.	Pounds per Sq. In.	Feet Head.	Pounds per Sq. In.	Feet Head.	Pounds per Sq. In.	Feet Head.	Pounds per Sq. In.
1	.43	30	12.99	95	41.14	250	108.27
2	.87	35	15.16	100	43.31	275	119.10
3	1.30	40	17.32	110	47.64	300	129.93
4	1.73	45	19.49	120	51.97	325	140.75
5	2.17	50	21.65	130	56.30	350	151.58
6	2.60	55	23.82	140	60.63	375	162.41
7	3.03	60	25.99	150	64.96	400	173.24
8	3.40	65	28.15	160	69.29	500	216.55
9	3.90	70	30.32	170	73.63	600	259.85
10	4.33	75	32.48	180	77.96	700	303.16
15	6.50	80	34.65	190	82.29	800	346.47
20	8.66	85	36.81	200	86.62	900	389.78
25	10.83	90	38.98	225	97.45	1000	433.09

TABLE
For Converting Pressure per Square Inch into Feet Head of Water.

Pounds per Sq. In.	Feet Head.	Pounds per Sq. In.	Feet Head.	Pounds per Sq. In.	Feet Head.	Pounds per Sq. In.	Feet Head.
1	2.31	30	69.27	95	219.35	250	577.24
2	4.62	35	80.81	100	230.90	275	634.95
3	6.93	40	92.36	110	253.98	300	692.69
4	9.24	45	103.90	120	277.07	325	750.41
5	11.54	50	115.45	130	300.16	350	808.13
6	13.85	55	126.99	140	323.25	375	865.89
7	16.16	60	138.54	150	346.34	400	922.58
8	18.47	65	150.08	160	369.43	500	1154.48
9	20.78	70	161.63	170	392.52	...	....
10	23.09	75	173.17	180	415.61	...	....
15	34.63	80	184.72	190	438.90	...	....
20	46.18	85	196.26	200	461.78	...	....
25	57.72	90	207.81	225	519.51	...	....

TABLE CONTRACTION OF METALS.

Cast Iron......................	$\frac{1}{8}$" per foot	..	=	.125"
Brass.........................	$\frac{3}{16}$" "	..	=	.187"
Gun Metal....................	$\frac{1}{6}$" "	..	=	.166"
Steel..........................	$\frac{3}{16}$" "	..	=	.187"
Malleable Cast Iron...........	$\frac{3}{16}$" "	..	=	.187"

WORKING PROPORTIONS FOR SHAFTING OF MEDIUM STEEL.

Diameter of Shaft in Inches.	Transmitting power, but subject to no bending action except its own weight.						Transmitting power, and subject to bending action of pulleys, belting, etc.					
	REVOLUTIONS PER MINUTE.					Maximum Distance in Feet Between Bearings.	REVOLUTIONS PER MINUTE.					Maximum Distance in Feet Between Bearings.
	100	150	200	250	300		100	150	200	250	300	
	HP.	HP.	HP.	HP.	HP.		HP.	HP.	HP.	HP.	HP.	
1½	7	10	14	17	20	11.7	5	7	10	12	14	6.8
1⅝	9	13	17	21	26	12.4	6	9	12	15	18	7.2
1¾	11	16	21	26	32	13.0	8	11	15	18	22	7.5
1⅞	13	20	26	33	40	13.6	9	14	19	23	28	7.9
2	16	24	32	40	48	14.2	11	17	23	28	34	8.2
2⅛	19	29	38	48	58	14.8	14	21	27	34	42	8.6
2¼	23	34	46	57	68	15.4	16	24	33	41	48	8.9
2⅜	27	40	54	67	80	16.0	19	29	38	48	58	9.2
2½	31	47	63	78	94	16.5	22	33	45	55	66	9.6
2¾	42	62	83	102	124	17.6	24	36	48	60	72	10.2
3	54	81	108	134	162	18.6	39	58	77	96	116	10.8
3¼	69	103	137	172	206	19.7	49	74	98	123	148	11.4
3½	86	129	172	215	258	20.7	61	92	123	153	184	12.0
3¾	105	158	211	264	316	21.6	75	113	151	188	226	12.5
4	128	192	256	320	384	22.6	91	137	183	228	274	13.1

MENSURATION TABLE.

(AREA.)

Parallelogram=base × perpendicular height.

Triangle=base × ½ perpendicular height.

Circle=diameter squared × .7854 or=radius squared × 3.1416.

Sector of a circle=length of arc × ½ radius.

Segment of circle=area of sector less area of triangle.

Side of square of equal area of circle=diameter × .8862; also =circumference × .2821.

Diameter of circle of equal area as square=side × 1.1284.

Trapezoid=half the sum of the parallel sides × perpendicular.

Trapezium, found by dividing into two triangles.

Parabola=base × ⅔ height.

Ellipse=longest diameter × shortest diameter × .7854.

Regular polygon=sum of its sides × ½ perpendicular distance from centre to sides.

Surface of cylinder=circumference × height + area of both ends.

Surface of sphere=diameter squared × 3.1416. Also=circumference × diameter.

Surface of frustrum=sum of circumference of the two ends × ½ the slant height + area of both ends.

Surface of cylindrical ring=thickness of ring added to the inner diameter × thickness × 9.8696.

Surface of cone=area of base + circumference of base × ½ slant height.

TABLE OF EQUIVALENTS OF VARIOUS WEIGHTS AND MEASURES.

	U. S. Gallons.	Imp. Gallons.	Cubic Feet.	Cubic Inches.	Short Tons.	Short Cwt.	Pounds	Litres.	Cu. Metres.
One U. S. Gallon equals	1.	.833	.133	231.	.00416	.0833	8.33	3.786	.00378
" Imp. Gallon "	1.2	1.	.16	277.274	.005	.1	10.	4.544	.00454
" Cubic Foot "	7.48	6.23	1.	1728.	.0312	.623	62.35	28.32	.0283
" Cubic Inch "	.0043	.0036	.00058	1.	.000018	.00036	.036	.0164	.000016
" Short Ton "	240.	200.	32.08	55440.	1.	20.	2000.	908.61	.9086
" Short Cwt. "	12.	10.	1.6	277.2	.05	1.	100.	45.43	.0454
" Pound "	.12	.1	0.16	27.72	.0005	.01	1.	.454	.00045
" Litre "	.264	.22	.035	61.0165	.0011	.022	2.2	1.	.001
" Cubic Metre "	264.18	220.06	35.31	61016.	1.1023	22.046	2204.62	1000.	1.

One pood=4.32 U. S. gallons=3.6 Imperial gallons=998 cubic inches=36 pounds.

One vedros=3.24 U. S. gallons=2.7 Imperial gallons=750 cubic inches=27 pounds.

One metre=39.37 inches=3.281 feet (act of U. S. Congress).

One inch=25.4 millimetres.

One miner's inch of water=12 U. S. gallons per minute.

A common water pail, filled, contains 19 pounds of water=2.272 U. S. gallons.

THE MEAN PRESSURE OF THE ATMOSPHERE is estimated at 14.7 pounds per square inch. With a perfect vacuum, at sea-level, it will therefore sustain a column of mercury 29.9 inches, or a column of water 33.9 feet high.

TO FIND THE CAPACITY OF A CYLINDER IN GALLONS. Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches: divide this amount by 231 (which is the cubical contents of a gallon in inches), and the product is the capacity in gallons.

TABLE

of Decimal Equivalents of Eighths, Sixteenths, Thirty-seconds and Sixty-fourths of an Inch.

Eighths		Thirty-seconds		Sixty-fourths		Sixty-fourths	
1/8	.125	1/32	.03125	1/64	.015625	33/64	.515625
1/4	.250	3/32	.09375	3/64	.046875	35/64	.546875
3/8	.375	5/32	.15625	5/64	.078125	37/64	.578125
1/2	.500	7/32	.21875	7/64	.109375	39/64	.609375
5/8	.625	9/32	.28125	9/64	.140625	41/64	.640625
3/4	.750	11/32	.34375	11/64	.171875	43/64	.671875
7/8	.875	13/32	.40625	13/64	.203125	45/64	.703125
Sixteenths		15/32	.46875	15/64	.234375	47/64	.734375
1/16	.0625	17/32	.53125	17/64	.265625	49/64	.765625
3/16	.1875	19/32	.59375	19/64	.296875	51/64	.796875
5/16	.3125	21/32	.65625	21/64	.328125	53/64	.828125
7/16	.4375	23/32	.71875	23/64	.359375	55/64	.859375
9/16	.5625	25/32	.78125	25/64	.390625	57/64	.890625
11/16	.6875	27/32	.84375	27/64	.421875	59/64	.921875
13/16	.8125	29/32	.90625	29/64	.453125	61/64	.953125
15/16	.9375	31/32	.96875	31/64	.484375	63/64	.984375

U. S. OR SELLERS' STANDARD OF BOLTS & NUTS.

Diameter of Bolt.	No. of Threads per Inch.	Diameter at Bottom of Thread.	Area at Bottom of Thread. Sq. Inches.	Width across Flats of Nut.
1/4	20	.185	.027	1/2
5/16	18	.240	.045	19/32
3/8	16	.294	.068	11/16
7/16	14	.344	.093	25/32
1/2	13	.400	.126	7/8
9/16	12	.454	.162	31/32
5/8	11	.507	.202	1 1/16
3/4	10	.620	.302	1 1/4
7/8	9	.731	.420	1 7/16
1	8	.837	.550	1 5/8
1 1/8	7	.940	.694	1 13/16
1 1/4	7	1.065	.893	2
1 3/8	6	1.160	1.057	2 3/16
1 1/2	6	1.284	1.295	2 3/8
1 5/8	5 1/2	1.389	1.515	2 9/16
1 3/4	5	1.490	1.746	2 3/4
1 7/8	5	1.615	2.051	2 15/16
2	4 1/2	1.712	2.302	3 1/8
2 1/4	4 1/2	1.962	3.023	3 1/2
2 1/2	4	2.175	3.719	3 7/8
2 3/4	4	2.425	4.620	4 1/4
3	3 1/2	2.628	5.428	4 5/8
3 1/4	3 1/2	2.878	6.510	5
3 1/2	3 1/4	3.100	7.548	5 3/8
3 3/4	3	3.317	8.641	5 3/4
4	3	3.566	9.993	6 1/8
4 1/4	2 7/8	3.825	11.329	6 1/2
4 1/2	2 3/4	4.027	12.743	6 7/8
4 3/4	2 5/8	4.255	14.226	7 1/4
5	2 1/2	4.480	15.763	7 5/8
5 1/4	2 1/2	4.730	17.572	8
5 1/2	2 3/8	5.053	19.267	8 3/8
5 3/4	2 3/8	5.203	21.262	8 3/4
6	2 1/4	5.423	23.098	9 1/8

TABLE.

EQUATION OF FEET AND INCHES TO METRES.

Ft.	In.	Metre.	Metre.	Fract. of Inch.	Decimal.
	1	.0254	.02460	$\frac{31}{32}$	.96875
	2	.0508	.02381	$\frac{15}{16}$	.9375
	3	.0762	.02301	$\frac{29}{32}$	.90625
	4	.1016	.02222	$\frac{7}{8}$	.875
	5	.1270	.02143	$\frac{27}{32}$	.84375
	6	.1524	.02063	$\frac{13}{16}$	.8125
	7	.1778	.01984	$\frac{25}{32}$	.78125
	8	.2032	.01904	$\frac{3}{4}$	.75
	9	.2286	.01825	$\frac{23}{32}$	.71875
	10	.2540	.01746	$\frac{11}{16}$	.6875
	11	.2794	.01666	$\frac{21}{32}$	.65625
	12	.3048	.01587	$\frac{5}{8}$	.625
2		.6096	.01508	$\frac{19}{32}$	.59375
3		.9144	.01428	$\frac{9}{16}$	.5625
4		1.2192	.01349	$\frac{17}{32}$	.53125
5		1.5240	.01269	$\frac{1}{2}$	.5
6		1.8288	.01190	$\frac{15}{32}$	.46875
7		2.1336	.01111	$\frac{7}{16}$	.4375
8		2.4384	.01031	$\frac{13}{32}$	.40625
9		2.7432	.00952	$\frac{3}{8}$	.375
10		3.0480	.00873	$\frac{11}{32}$	.34375
11		3.3528	.00793	$\frac{5}{16}$	.3125
12		3.6576	.00714	$\frac{9}{32}$	.28125
13		3.9624	.00634	$\frac{1}{4}$	.25
14		4.2672	.00555	$\frac{7}{32}$	.21875
15		4.5720	.00476	$\frac{3}{16}$	.1875
16		4.8768	.00396	$\frac{5}{32}$	.15625
17		5.1816	.00317	$\frac{1}{8}$	.125
18		5.4864	.00238	$\frac{3}{32}$	.09375
19		5.7912	.00158	$\frac{1}{16}$	.0625
20		6.0960	.00079	$\frac{1}{32}$	.03125
21		6.4008	.00039	$\frac{1}{64}$	.015625

TABLE OF AREA OF CIRCLES.

Diameter.	Area.	Diameter.	Area.	Diameter.	Area.	Diameter.	Area.
1/8	0.0123	10	78.54	30	706.86	65	3318.3
1/4	0.0491	10 1/2	86.59	31	754.76	66	3421.2
3/8	0.1104	11	95.03	32	804.24	67	3525.6
1/2	0.1963	11 1/2	103.86	33	855.30	68	3631.6
5/8	0.3068	12	113.09	34	907.92	69	3739.2
3/4	0.4418	12 1/2	122.71	35	962.11	70	3848.4
7/8	0.6013	13	132.73	36	1017.8	71	3959.2
1	0.7854	13 1/2	143.13	37	1075.2	72	4071.5
1 1/8	0.9940	14	153.93	38	1134.1	73	4185.4
1 1/4	1.227	14 1/2	165.13	39	1194.5	74	4300.8
1 3/8	1.484	15	176.71	40	1256.6	75	4417.8
1 1/2	1.767	15 1/2	188.69	41	1320.2	76	4536.4
1 5/8	2.073	16	201.06	42	1385.4	77	4656.6
1 3/4	2.405	16 1/2	213.82	43	1452.2	78	4778.3
1 7/8	2.761	17	226.98	44	1520.5	79	4901.6
2	3.141	17 1/2	240.52	45	1590.4	80	5026.5
2 1/4	3.976	18	254.46	46	1661.9	81	5153.0
2 1/2	4.908	18 1/2	268.80	47	1734.9	82	5281.0
2 3/4	5.939	19	283.52	48	1809.5	83	5410.6
3	7.068	19 1/2	298.64	49	1885.7	84	5541.7
3 1/4	8.295	20	314.16	50	1963.5	85	5674.5
3 1/2	9.621	20 1/2	330.06	51	2042.8	86	5808.8
3 3/4	11.044	21	346.36	52	2123.7	87	5944.6
4	12.566	21 1/2	363.05	53	2206.1	88	6082.1
4 1/2	15.904	22	380.13	54	2290.2	89	6221.1
5	19.635	22 1/2	397.60	55	2375.8	90	6361.7
5 1/2	23.758	23	415.47	56	2463.0	91	6503.9
6	28.274	23 1/2	433.73	57	2551.7	92	6647.6
6 1/2	33.183	24	452.39	58	2642.0	93	6792.9
7	38.484	24 1/2	471.43	59	2733.9	94	6939.8
7 1/2	44.178	25	490.87	60	2827.4	95	7088.2
8	50.265	26	530.93	61	2922.4	96	7238.2
8 1/2	56.745	27	572.55	62	3019.0	97	7389.8
9	63.617	28	615.75	63	3117.2	98	7542.9
9 1/2	70.882	29	660.52	64	3216.9	99	7697.7

To compute the area of a diameter greater than any in the above table:

RULE.—Divide the dimension by 2, 3, 4, etc., if practicable, until it is reduced to a quotient to be found in the table, then multiply the tabular area of the quotient by the square of the factor. The product will be the area required.

EXAMPLE.—What is area of diameter of 150? 150÷5=30. Tabular area of 30 = 706.86 which × 25 = 17,671.5, area required.

CIRCUMFERENCE OF CIRCLES.

Diameter.	Circumference.	Diameter.	Circumference.	Diameter.	Circumference.	Diameter.	Circumference.
⅛	.3927	10	31.41	30	94.24	65	204.2
¼	.7854	10½	32.98	31	97.38	66	207.3
⅜	1.178	11	34.55	32	100.5	67	210.4
½	1.570	11½	36.12	33	103.6	68	213.6
⅝	1.963	12	37.69	34	106.8	69	216.7
¾	2.356	12½	39.27	35	109.9	70	219.9
⅞	2.748	13	40.84	36	113.0	71	223.0
1	3.141	13½	42.41	37	116.2	72	226.1
1⅛	3.534	14	43.98	38	119.3	73	229.3
1¼	3.927	14½	45.55	39	122.5	74	232.4
1⅜	4.319	15	47.12	40	125.6	75	235.6
1½	4.712	15½	48.69	41	128.8	76	238.7
1⅝	5.105	16	50.26	42	131.9	77	241.9
1¾	5.497	16½	51.83	43	135.0	78	245.0
1⅞	5.890	17	53.40	44	138.2	79	248.1
2	6.283	17½	54.97	45	141.3	80	251.3
2¼	7.068	18	56.54	46	144.5	81	254.4
2½	7.854	18½	58.11	47	147.6	82	257.6
2¾	8.639	19	59.69	48	150.7	83	260.7
3	9.424	19½	61.26	49	153.9	84	263.8
3¼	10.21	20	62.83	50	157.0	85	267.0
3½	10.99	20½	64.40	51	160.2	86	270.1
3¾	11.78	21	65.97	52	163.3	87	273.3
4	12.56	21½	67.54	53	166.5	88	276.4
4½	14.13	22	69.11	54	169.6	89	279.6
5	15.70	22½	70.68	55	172.7	90	282.7
5½	17.27	23	72.25	56	175.9	91	285.8
6	18.84	23½	73.82	57	179.0	92	289.0
6½	20.42	24	75.39	58	182.2	93	292.1
7	21.99	24½	76.96	59	185.3	94	295.3
7½	23.56	25	78.54	60	188.4	95	298.4
8	25.13	26	81.68	61	191.6	96	301.5
8½	26.70	27	84.82	62	194.7	97	304.7
9	28.27	28	87.96	63	197.9	98	307.8
9½	29.84	29	91.10	64	201.0	99	311.0

TABLE OF HEAT UNITS OF FUELS.

	Heat Units per Pound.
Anthracite coal	15,000 to 16,000
Bituminous coal	14,000 to 15,000
Coke	10,000 to 14,000
Hardwood	8,000 to 9,000
Charcoal	12,000
Peat	10,000
Coal peat briquettes	10,000 to 13,000
Kerosene	20,000 to 25,000
Gasolene	20,000 to 25,000
Boston gas	650 per cubic foot

This gives a basis for an approximate estimate of the cost of an equal amount of heat obtained from each of the fuels:

A British thermal unit is the heat required to heat one pound of water one degree Fahr. The table was prepared by Prof. C. L. Norton.

TABLE.

The sizes of twist drills to be used in boring holes to be reamed with pipe reamer, and threaded with pipe tap, are as follows:

SIZE, TAP	DIAMETER, DRILL	SIZE, TAP	DIAMETER, DRILL
$\frac{1}{8}$ inch	$\frac{21}{64}$ inch	$1\frac{1}{4}$ inches	$1\frac{15}{32}$ inches
$\frac{1}{4}$ inch	$\frac{29}{64}$ inch	$1\frac{1}{2}$ inches	$1\frac{23}{32}$ inches
$\frac{3}{8}$ inch	$\frac{19}{32}$ inch	2 inches	$2\frac{3}{16}$ inches
$\frac{1}{2}$ inch	$\frac{23}{32}$ inch	$2\frac{1}{2}$ inches	$2\frac{11}{16}$ inches
$\frac{3}{4}$ inch	$\frac{15}{16}$ inch	3 inches	$3\frac{5}{16}$ inches
1 inch	$1\frac{1}{8}$ inch		

TABLE.

WIND LOADS.

VELOCITY **Miles Hour.**	**PRESSURE** **Lbs. Square Foot.**
10	0.4 fresh breeze
20	1.6 stiff breeze
30	3.6 strong wind
40	6.4 high wind
50	10.0 storm
60	14.4 violent storm
80	25.6 hurricane
100	40.0 violent hurricane

Ascertained by the U. S. Signal Service at Mt. Washington, N. H.

Any one, and more especially the attentive student, can with the least trouble avail himself of the subject matter contained in this work by doing as indicated in the following old English couplet quoted by Chas. Reade.

" For index-reading turns no student pale,
Yet takes the eel of science by the tail."

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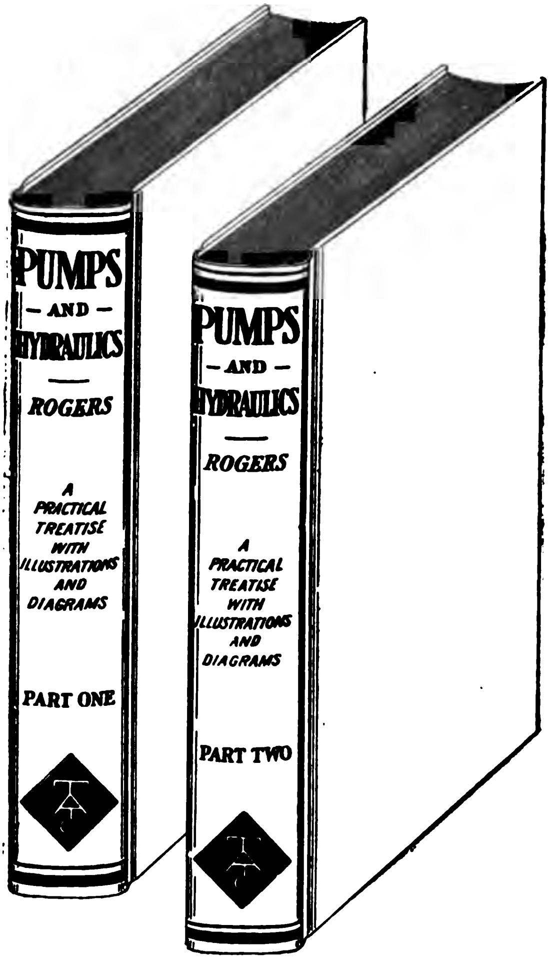
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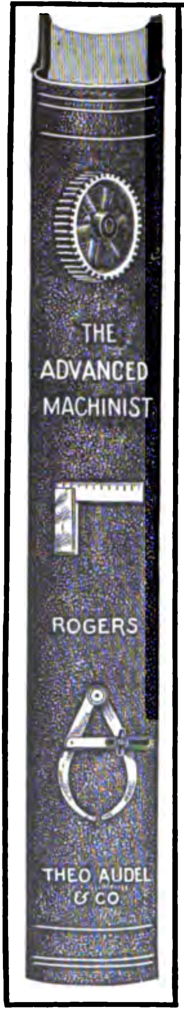

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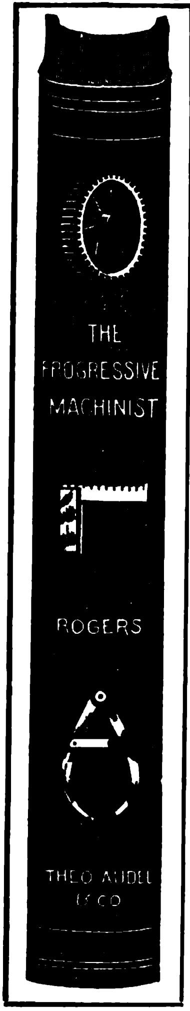

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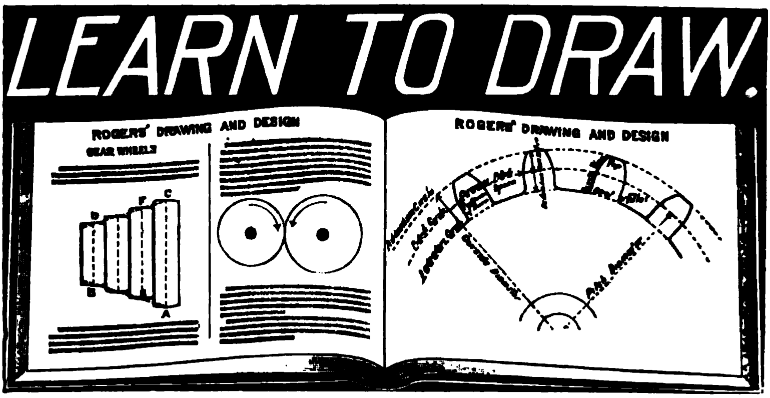

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